School Science

VOL. II] JANUARY, 1903. [No. 7

REVISION OF PHYSICAL THEORY.*

BY PROF. HENRY S. CARHART.

Professor of Physics in the University of Michigan.

Physics, as a rational body of knowledge, is hardy and of slow growth. It has none of the characteristics of the mushroom, but rather those of the oak. It has not grown up in a night, nor even in a century. On the contrary it is the product of many centuries, and it has drawn its nourishment from many lands.

From another point of view it resembles a coral island which slowly emerges from the sea, with occasional subsidences and engulphing in the ocean. When it has finally risen from the water and has acquired soil from wind and wave, stately palms crown it and it becomes green with tropical verdure.

The essential element in physics which I wish to emphasize is *growth*. Not death and decay, but the development of living tissue, enlargement by accretion, assimilation, and cellular growth. Now growth and development mean modification, elaboration, flower and fruit, the bare limbs of winter and the grateful foliage of summer. They mean an incessant struggle upwards toward the light.

Physics is a living body of truth, a growing science; and as such it exhibits incessant change. It is sometimes profitable and suggestive to take a survey of some of these changes and to note the appearance and sway of physical theories, followed frequently

* An address delivered before the Central Association of Physics Teachers, Nov. 28, 1902.

by their disappearance, either gradually or with theatrical suddenness. A mighty magician appears, or some new and astounding fact emerges into view; theories are called upon to justify their title, and a readjustment of scientific doctrine becomes imperative. The physicist, who is more intent on ascertaining truth than preserving consistency, holds to a physical theory no longer than he finds it able to furnish support and lend aid. The laws of nature represent the survivals of the fittest theories. Disappearance denotes unfitness to survive. A theory may contain the kernel of a great truth, but overlaid and surrounded with husks and shucks. Time removes these. They may serve a useful purpose in guarding and preserving the kernel till the time arrives for it to germinate, when temperature and soil and sun are favorable. The husk then decays while the inner living principle survives.

It is not difficult to recall instances illustrating the revision which physical theories have undergone in the past. We are all familiar with the famous contest in the scientific world between the corpuscular and the undulatory theory of light. It is not so commonly known that the wave theory was the first to receive the support of eminent men of science. No theory worthy of the name existed prior to the time of Huygens. At a meeting of the French Academy of Sciences in 1678, and in the presence of astronomers Roemer and Cassini, Huygens read a remarkable paper on the wave theory of light. Bradley, the Astronomer Royal of England, had already confirmed Roemer's conclusion from observations on Jupiter's inner satellite that the propagation of light is gradual and not instantaneous. Thus two methods of determining this constant of nature had been discovered—Roemer's by the eclipses of Jupiter's satellite, and Bradley's by the phenomenon now known as aberration. In 1690 Huygens published his *Traité de la Lumière.* In this he developed the principle relating to the propagation of waves which continues to be known by his name to this day. It assumes that each point of a wave-front becomes a new center of disturbance for secondary waves, which coalesce into a succeeding wave-front. Huygens definitely assumed the existence of an ether, and explained reflection and refraction by methods which are still current in physical litera-

ture. He even gave constructions for the path of the ordinary and extraordinary rays in Iceland spar and showed that both are polarized. But a fatal defect was his assumption of longitudinal vibrations and his inability to give a satisfactory account of rectilinear propagation.

Newton was familiar with the undulatory theory and distinctly recognized its capability of explaining the colors of thin plates. The theory, he says, "is sufficient to explicate all the ordinary phenomena of those plates or bubbles, and also of all natural bodies, whose parts are like so many fragments of such plates." He nevertheless rejected it in favor of his corpuscular theory, and by his powerful authority biased the minds of physicists for a whole century. The corpuscular doctrine held sway against the arguments of Hooke, Huygens, Young and Fresnel till Foucault devised the crucial experiment to determine whether the velocity of light in water is less or greater than in air. The Newtonian theory required that it be greater; the undulatory theory that it be less. Nature said it is less, and the Newtonian theory retired into the background.

Maxwell, with great penetration and power, laid the foundations of a fundamentally new method of regarding the undulations of light. It remained for the lamented Heinrich Hertz to confirm the Maxwellian theory by a series of the most brilliant experiments of modern times. Since then light has taken its place as an electromagnetic phenomenon; and the rapid extension of the area over which electromagnetic waves of long period may be recognized has finally enabled them to bridge the Atlantic.

It must not be inferred, however, that the undulatory theory of light has been abandoned or superseded. The electromagnetic theory of light is only a modification of the wave theory; it describes something of the mechanism of wave motion in the ether, and classifies the energy in light as electromagnetic in character. It is now possible to produce waves in the ether indefinitely longer than those affecting the eye as light, and to recognize them by appropriate receiving apparatus. Modern discovery consists not so much in the discovery of long ether waves as in the recognition of their existence and the means of detecting them. The wireless messages of Marconi, wonderful as they are, are but

feeble imitations of those incessantly pouring in upon us from the sun. These have dashed the earth with gorgeous colors and dotted the oceans with the greenest of isles. Their swift-winged messages have brought to man some knowledge of other worlds and other suns than ours.

A scarcely less instructive change of physical theory took place during the past century regarding the nature of heat. Able men had not been lacking who had suggested a theory dimly resembling the one held at the present time, but the materialistic doctrine of heat was still generally held by both physicists and chemists, along with its congener, phlogiston. Descartes, Bacon, Hobbs and Boyle all suggested that heat and motion were intimately associated. Indeed Newton himself asked, "Is not heat conveyed by the vibrations of a much subtler medium than air?" Unfortunately the great Cambridge philosopher decided in favor of the materialistic theory, the adoption of phlogiston followed, and then the bald doctrine of material caloric after Newton had long been in his grave.

You are all familiar with the first staggering blow at the doctrine of caloric delivered by Count Rumford in 1798. His noble contribution to the science of thermodynamics counts for so much that we are disinclined to believe he was a Tory in North Woburn (especially that the Revolutionary War is now over and England ungrudgingly acknowledges that we were right); and we are almost ready to forgive his desertion of wife and child, when he fled to England to become a somewhat inactive enemy of the land of his birth. We must not forget either that Rumford was instrumental in founding the Royal Institution in London. That establishment for research in Albermarle street has been prolific in great discoveries. The mere mention of such names as Davy, Faraday, Rayleigh, and Dewar is sufficient to call up a long line of the most splendid contributions to science, which have been freely given to the world by this same institution for research.

Rumford's strong argument, derived from the continuous production of heat in boring cannon, was to the effect that whatever could be obtained in an apparently inexhaustible quantity, when a blunt plunger was turned against friction in a bronze cannon, could not be material. The youthful Davy, then only

twenty years of age, clinched the argument by showing that ice could be melted by friction against ice. Davy, with a modesty becoming his youth, hesitated to draw the logical deduction from his experiment which it abundantly justified till some twelve years later. The caloric theory survived, strange to say, for more than half a century after the experiments of Rumford and Davy had condemned and disproved it. As late as 1856, it received the preference over the dynamic theory in an article on "Heat" in the Encyclopædia Britannica.

When, however, the doctrine of the Conservation of Energy emerged into the view of those having clear scientific vision, it was perceived that heat is neither material, nor is it the mere motion of material particles; not "a mode of motion," but the energy of that motion. Heat is energy convertible into all other forms of energy, and the final form which all energy assumes in the process of dissipation. Hence the great work of Joule and Rowland in determining "the mechanical equivalent of heat," one of the most important constants of nature which the mind of man has evolved as a corollary from the doctrine of the Conservation of Energy. May I take occasion in passing to remark that, since heat is energy and not a material, it is unscientific to apply to it the word "temperature." Much that has been written on the subject of the application of thermodynamics to the very modern subject of physical chemistry contains expressions based on the antiquated concepts of the caloric theory. Not a few writers, including Nernst and his school, speak of a quantity of heat falling from one temperature to another, or of raising a quantity of heat from one temperature to a higher one, as if heat were a substance called "caloric." It is indeed time that eighteenth century conceptions about heat were eliminated from treatises and textbooks.

The mention of physical chemistry brings to mind many changes that have taken place in physical concepts within the past two decades. Just twenty years ago Helmholtz said to the writer, as the latter was about to leave his laboratory, that the most promising field of labor was then on the border land between physics and chemistry. Subsequent events show that Helmholtz himself was at that time at work in this field, and at this distance of time his words seem prophetic.

The old formal scholastic distinction between physics and chemistry has disappeared. It is no longer true in any sense that physics is concerned with the molecule, while chemistry has to do with the atomic constitution of matter. So far afield have we gone from this old hard and fast division that the modern physicist does not pause at atoms even. He has now to deal with corpuscles or electrons, whose mass is perhaps little in excess of 1/1,000th of an atom of hydrogen. The brilliant work of Professor J. J. Thomson in this field has given rise to new concepts of matter, and has taught us that there is more in an exhausted receiver then we have hitherto dreamed of in our philosophy.

Knowledge of the properties of matter has been enormously extended in two directions, the one in high vacua, and the other at low temperatures. The revolutionary discoveries of Sir William Crookes, beginning about 1875, on electric discharges in high vacua have opened a new world of the most bewitching interest. We now have Lenard rays, Roentgen rays, Becquerel rays, and radio-active substances emitting radiations of most pernicious activity. It has thus been ascertained that mankind has been living in the midst of a multitude of unsurpassed wonders and of properties that no one suspected.

The expression "fixed gases" has not yet faded from our memories. I well remember the wide reputation gained by my old professor of chemistry in college because of his success in liquefying carbon dioxide a short time previously. The solidification of this substance is now a common lecture room experiment, and the "fixed gases" then known have all followed in the train of carbon dioxide. Every gaseous body but one definitely known to the chemist has now been reduced to the solid state. For the last dozen years Professor Dewar has been engaged at the Royal Institution in London on these low temperature experiments. Ten years ago I saw him turn a spigot and out of it flowed liquid oxygen mixed with solid carbon dioxide, from which it was separated by passing the extremely cold liquid through an ordinary filter paper. Even then he was able to liquefy air under atmospheric pressure by means of the low temperature obtained by the evaporation of liquid oxygen in an exhausted received. Hydrogen has followed, not to the point of liquefaction only, but to the state of

a clear ice-like solid at a temperature only *thirteen degrees* above the zero of the absolute scale, or at a temperature of 260 degrees below the zero of the Centigrade scale. Its density in the liquid form is only one-fourteenth that of water, and the only solid that will float on it is pith. Its specific heat, on the other hand, is five times that of water, and its coefficient of expansion is ten times that of a gas. It does not conduct electricity, strange to say, in either the liquid or the solid state. It is therefore non-metallic, and it is also slightly diamagnetic. The study of the properties and chemical relations of hydrogen led great physicists and chemists like Faraday, Dumas, Daniell, Graham, and Andrews, to entertain the view that in either the liquid or the solid state it would exhibit metallic properties. The case of hydrogen shows, as Dewar says, that "no theoretical forecast, however apparently justified by analogy, can be finally accepted as true until confirmed by actual experiment."

Another revision of physical concepts, which still remains within the realm of theory, is the modern doctrine of osmotic pressure, and the related doctrine of electrolytic dissociation. The theory of the solution of a solid in a liquid solvent remained in a chaotic state up to a period fifteen years ago, when van't Hoff showed that when sugar is dissolved in water the dissolved particles follow the laws of Boyle and Gay-Lussac for gases; in other words, we may apply to the sugar in solution the gas equation, $PV = RT$, and may demonstrate that if P is the osmotic pressure and V the volume containing a gram-molecule of the sugar, R has the same value as in the case of a gas, that is, about 83,000,000. Such a remarkable result can scarcely be a coincidence. Whether great molecular mobility is given to a substance by causing it to assume the gaseous form, or by dissolving it in a proper solvent, it follows in both cases the same laws as regards the relations between volume, pressure and temperature.

I have stated the principle too broadly, because substances in solution, which conduct electricity and undergo electrolysis invariably exhibit a larger osmotic pressure than they should to conform to the gas law. This increase is accounted for by the dissociation into electrically charged ions, which the substance undergoes in solution, an ion exerting the same osmotic pressure as a molecule.

Van't Hoff expressed the relation between gas pressure and osmotic pressure as follows: "The pressure which gas exerts at a given temperature, if a definite number of molecules is contained in a definite volume, is equal to the osmotic pressure which is produced by most substances under the same conditions, if they are dissolved in any given liquid." But the "most substances" of van't Hoff, Arrhenius showed do not include many aqueous solutions in the sense that these latter exert a much greater osmotic pressure than is required by the gas law. Hence Arrhenius made a distinction between active and inactive molecules in solution, the active molecules including those whose ions are independent of one another in their movements. The remaining molecules, not dissociated into independent ions, are inactive. He then proceeds to show that van't Hoff's law holds not only for most, but for all substances, even for those which had hitherto been regarded as exceptions, that is, electrolytes in aqueous solution.

A corollary of this law is that the active molecules alone conduct electrolytically, the inactive molecules taking no part in the process. In other words, conductivity is a property of the charged ions into which the dissolved substance is dissociated.

The theory of electric conductivity in electrolytes has undergone modifications in successive steps or stages. Very soon after the electrolysis of a compound liquid had been effected, Grothuss, then only twenty years of age, proposed the theory of electric conductivity in liquids which bears his name; it was in a paper published at Rome in 1805, and bearing the title "Memoir on the decomposition of water and of other bodies, which it holds in solution, by the aid of galvanic electricity." The theory involves alternate separation and recombination of molecules. To accomplish this segregation of oxygen and hydrogen, for example, a definite E. M. F. must be applied to the solution by means of the electrodes. A smaller potential diffenerce than that required to effect the segregation would not produce any electrolysis nor the flow of a current. But it was afterwards shown, as Clausius pointed out in 1857, that even the weakest E. M. F. produces a current through an electroloyte and that it follows Ohm's law. Hence the modification of the Grothuss theory proposed by Clausius that the ions of substance in solution are not permanently

united with one another, but a few of them are always present in a temporarily uncombined state, and wandering about till they again combine with other partners. This temporary dissociation Clausius conceived to be due to the agitation of heat, and he gave cogent chemical reasons in support of his hypothesis. These free ions are then present in a solution to conduct a current when the potential difference is below the value required for actual visible decomposition.

When the voltameter is composed of metallic electrodes immersed in a salt solution of the same metal, copper electrodes in copper sulphate solution for example, the current is simply proportional to the potential difference between the electrodes, no sudden change in its value is observed, and the metal is simply transported across from one electrode to the other. If, however, at least one of the products of the electrolysis is a gas, which occurs when the anode is platinum, then the appearance of the liberated gas when the potential difference reaches a well-defined value, is a signal for a rapid increase of the current and of the visible decomposition. Since work must be done against atmospheric pressure when a gas is liberated, the E. M. F. must have a corresponding determinable value before the required work can be accomplished.

From an electrical point of view the Clausius modification of the theory of Grothuss appeared to answer the requirements. But the study of the conductivity of electrolytes, by Kohlrausch especially, showed that the molecular conductivity, or the conductivity of a gram-molecule of the substance in a solution placed between plate electrodes one centimeter apart, depends on the dilution; the greater the dilution, the greater the molecular conductivity. This fact demanded an advance on the theory of Clausius. The advance step consisted in assuming that the dissociation which Clausius conceived to be casual and indeterminate in amount, is permanent and occurs when the substance is dissolved. Hence the more dilute the solution, the larger the proportion of molecules which undergo dissociation and become *active* in the sense in which Arrhenius used the word. At extreme or infinite dilution, all the molecules in the solution are dissociated into ions, some positively charged and the rest negatively.

The current through an electrolyte consists of the sum of the positive and negative charges actually carried through the solution by the migration of the positive ions toward the cathode and the negative ions toward the anode.

The theory of electric conductivity through solutions is intimately connected with the theory of a voltaic cell. It has thus come about that the modern dissociation theory has led to an entirely new view of the mechanism in a primary cell, and especially the origin of its E. M. F. A heated controversy was kept up for three generations over the origin and seat of the E. M. F. in a voltaic cell. I know of no other dispute so persistent and long sustained, unless it be a Kentucky family feud. Volta's theory that the origin of the E. M. F. is at the contact of the two metals had able supporters especially in Germany, where the names of Poggendorff, Fechner, and Ohm were names to conjure with. On the other hand Fabroni, Wollaston, Ritter, Becquerel, de la Rive and the great Faraday held that the source of voltaic electricity is chemical action. Then came the doctrine of the Conservation of Energy and the immediate conclusion that mere contact of metals could not give rise to the supply of electric energy which a cell is able to furnish. It will be observed that when Helmholtz, then only twenty-six years of age, presented his paper on "Die Erhaltung der Kraft," or as we now express it, The Conservation of Energy, for publication in *Poggendorff's Annalen,* it was rejected by this same Poggendorff who had persistently held to the contact theory. Whether Poggendorff was then the responsible editor of the journal, I am unable to say. He lived for thirty years after this time.

Helmholtz's paper was read before the Physical Society of Berlin in 1847, and was published the same year in pamphlet form. It attracted little attention for six years when, strange to relate, it was vigorously attacked by Clausius, who lived long enough, however, to see his error and to recognize the greatness of Helmholtz.

After the introduction of the principle of the Conservation of Energy, Thomson applied it to the voltaic cell and calculated the E. M. F. on the basis that the electric energy evolved equals the chemical energy transformed. From the point of view of

energy, a voltaic cell is a device for the direct conversion of potential chemical energy into the energy of an electric current. The question arose whether all the chemical energy transformed in a voltaic cell is thus converted into electrical energy? Thomson and Helmholtz at first answered the question in the affirmative, and the principle of equating the two forms of energy was thereafter known as the Thomson principle. According to this view it is a simple matter to calculate the E. M. F. of any given combination from the heats of formation of the compounds undergoing chemical change. The quantity of electricity transported through the cell when one gram-equivalent of zinc enters into solution and *a* gram-equivalent of other substances undergoes a concurrent change may be calculated from Faraday's laws of electrolysis. It is 96,540 coulombs. This quantity multiplied by the E. M. F. of the cell equals the electrical energy given out while one gram-equivalent of zinc goes into solution. If this product is placed equal to the algebraic sum of the heats of formation of all the chemical changes involved in the cell, the E. M. F. is readily obtained from the equation. Thus the heat of formation of a gram-equivalent of zinc sulphate, according to Berthelot, is 121,000 calories; of copper sulphate, 95,700 calories. The difference is 25,300 calories. Then the reaction in a Daniell cell may be written

$$Zn + CuSO_4 = ZnSO_4 + Cu + 25{,}300 \text{ calories.}$$

$$\text{Further, } EQ = 25{,}300 \times 4.19 \text{ calories,}$$

where Q equals 96,540 coulombs. From this equation E is 1.098 volts, the E. M. F. of the cell. The value of the E. M. F. of the Daniell cell calculated in this way agrees very closely with the observed value. It was soon found, however, that other cells did not show such good agreement with the theory. In some the E. M. F. is smaller than the calculated value, and in others it is larger. Finally, Willard Gibbs in America and Helmholtz in Germany independently expressed the true relationship between the chemical energy transformed and the electrical energy given out. The Gibbs-Helmholtz equation may be conveniently written as follows:

$$E = \frac{H}{q} + T\frac{dE}{dT},$$

in which H is the sum of all the heats of formation expressed in mechanical measure, q is the quantity of electricity required to transport one chemical equivalent of any substance (96,540 coulombs), T is the absolute temperature, and dE/dT the temperature coefficient of the E. M. F. of the cell. It is obvious from this equation that E is smaller than the E. M. F. calculated from thermal data alone whenever the temperature coefficient is negative; and it is larger when the temperature coefficient is positive. In the former case only a portion of the transformed chemical energy appears as the energy of the current; the remainder heats the cell. In the latter case, the energy given out by the cell is in excess of the chemical energy transformed, or the cell converts some of its heat into electrical energy, and so cools in action.

The Gibbs-Helmholtz equation represents our most assured knowledge of the relation between the chemical, electrical, and thermal quantities involved in a voltaic cell, and it has been fully established by experiment.

It has also been demonstrated that the temperature coefficient of a voltaic cell is equal to the sum of all the thermo-electromotive forces, taken with their proper sign, at all contacts of dissimilar substances in the cell. For example, the thermo-electromotive force betweet zinc and a solution of zinc sulphate is directed from the solution to the metal. The same is true of copper and copper sulphate, while the thermo-electromotive force between equi-dense solutions of the sulphates of zinc and copper is practically zero. If, therefore, a Daniell cell be so constructed that one side or electrode may be heated independently of the other, it will have a positive coefficient if the positive electrode and the solution about it be heated, and a negative coefficient if the negative side alone be heated. This follows from the fact that the direction of the E. M. F. of the cell as a whole is from the zinc to the copper through the cell. Hence the thermo-electromotive force at the copper electrode is in the same direction as that of the cell, while that at the zinc electrode is in the opposite direction. These two thermo-electromotive forces are very nearly equal to each other, and the temperature coefficient of the Daniell cell as a whole is therefore very small. The same method applies to other cells.

It thus appears that the heat generated or absorbed, corres-

ponding with the sign of the temperature coefficient, may be localized in the cell. For example, in the Daniell cell the passage of a current generates heat at the zinc electrode, where the current flows against the thermo-electromotive force at the surface of the zinc; at the same time heat is absorbed at the copper electrode because the thermal E. M. F. there is in the same direction as the current. A difference of temperature is thus established between the two sides of the cell, which in a given time is proportional to the first power of the current. These statements have been fully established experimentally. If the quantities of heat generated on the one side and absorbed on the other are equal to each other, then the temperature coefficient of the cell is zero and the chemical energy transformed equals the electrical energy given out.

The Gibbs-Helmholtz equation, modified as described, is a fairly complete expression of the voltaic cell from an energy point of view. It needs only the further addition of expressing the heat of formation of the chemical compounds involved as a function of the density of the solutions.

The Nernst theory of a voltaic cell is based first of all on the theory of osmotic pressure developed by van't Hoff. To this theory it adds the assumption that metals exhibit a tendency to go into the ionic state when immersed in an electrolyte. A supposed analogy is found in the tendency of liquids to evaporate, the evaporation in a closed space continuing until the vapor pressure is equal to the tendency of the liquid to pass into vapor. In the same way the osmotic pressure of a solution saturated with metallic ions may be looked upon as a measure of the "solution pressure" of the metal in contact with it. This "solution pressure" of Nernst is supposed to measure the tendency of a metal to pass into free ions in an electrolyte. If now a metallic ion passes from a solution pressure P into the state of a free ion under an osmotic pressure p, then Nernst conceives that the work done is the same as when a gas passes from the one pressure to the other. The well known formula for the work in the case of a gas is $RT. \log P/p$. This is the work done at one electrode when a gram-equivalent of metal passes

into solution. Substituting the value of the gas constant R, and passing to common logarithms, we get

$$E = 0.0002\,T \log \frac{P}{p}.$$

This expression applies to metals whose valence is one. If the valence is n, and if we take into consideration both electrodes, we have

$$E = 0.0002\,T \left(\frac{1}{n} \log. \frac{P}{p} - \frac{1}{n'} \log \frac{P'}{p'} \right)$$

as the equation for the E.M.F. due to solution pressure and osmotic pressure only. If two electrolytes are employed, a small effect may be produced at the contact of the two.

It will be observed that both the Gibbs-Helmholtz and the Nernst formulas involve the doctrine that the seat of the E.M.F. of a voltaic cell is at the contact of dissimilar substances in the cell. Neither is, however, a contact theory, but both reason from the theorems of thermodynamics. The two formulas represent two ways of approaching the problem. They are not antagonistic, but complementary rather. Nernst's formula gives a somewhat more detailed insight into the mechanism of a cell, but it involves a number of hypotheses which the most ardent admirer of the theory can hardly claim to have been established by experiment. The Gibbs-Helmholtz formula, even when including the localization of the heat effects, rests on a secure basis of experimental facts.

The Nernst formula gives no definite account of the temperature coefficient of a cell, nor of the relation of this coefficient to the electrical energy evolved. The thermodynamic method of Gibbs and Helmholtz furnishes the most secure foundation for the investigation of a cell from the point of view of energy changes, without the assumption of any hypotheses, and without exposing to view the exact mechanism beyond the application to the problem of thermo-electromotive forces.

"And what shall I more say? for the time would fail me to tell of Gideon, and of Barak, and of Samson, and of Jephthah; of David also, and of Solomon, and of the prophets." I will only

recall to your minds that the superficial distinctions between electricity developed by friction, by voltaic cells, by heat, and by electromagnetic induction have all gradually disappeared, since a condenser may be charged or a current be set flowing by electric pressure, however produced. All the phenomena formerly produced by electrostatic machines are now produced by induction coils or by alternating currents of high potential. In fact, many new phenomena have been added by the high frequency discharges obtained by alternating currents. Lightning has, so to speak, been analyzed into the "steady strain" and the "impulsive rush" discharges of Sir Oliver Lodge, with attendant oscillations along a well-worn track till the energy is dissipated in heat. Hence the interesting resonance effects, which bring out a striking analogy between stationary waves in sound and stationary waves or surges of electricity.

Again, in magnetism, the crude theory of a magnetic fluid, adhering like a liquid drop to the poles of a magnet, has given place since the time of the immortal Faraday to the conception of magnetic induction, and lines of force. These lend themselves to experimental investigation to such an extent that today we may design a magnetic circuit to the minutest detail with nearly or quite the same approach to accuracy that is possible with an electric circuit. The law of the magnetic circuit, thanks to Rowland and others, has now taken its place alongside the law of the electric circuit as established by Ohm.

Note, also, how our friends and fellow workers, the mathematicians, have been obliged to give up their favorite "action at a distance" doctrine. Faraday and Maxwell taught them that no action takes place at a distance without the agency of an intervening medium. As soon as the cannon-ball theory of light and radiant heat had been relegated into a decent oblivion, the necessity arose for a revision of all the physical theories of action involving the law of inverse squares. In fact this law fails except under ideal conditions, and especially in the case of gravitation. Indeed gravitational astronomy has not kept abreast of modern physical astronomy as represented by such eminent workers as Pickering of Cambridge and Campbell of Mt. Hamilton. Great renown awaits the physical astronomer who will demonstrate be-

yond doubt whether gravitation acts through the medium of the ether, and whether it involves the element of time in transmission.

Finally, a lesson for the present may be drawn from the history of theory in the past. Theories are only helps or scaffolds. They are necessary working devices which aid in the advance of the edifice, and finally disappear like the staging. Use them only as props and temporary expedients, not until the whole edifice is finished, but until some grand arch is completed, some minaret or tower emerges against the clear sky, or the light streams in through some noble window.

It is often darkest just before the dawn. Sometimes we emerge into the bright light with a suddenness that blinds before the eye adjusts itself to the new illumination. One dreary day in April I took the train in Switzerland over the St. Gotthard route. We entered the north end of the tunnel with a clouded sky and snow flakes swirling through the air. Ten minutes passed in the darkness a thousand feet beneath the village of Andermatt, fifteen, seventeen, and then the train ran out on the Italian side of the great divide—into a burst of sunshine and clear sky and white-capped Alpine peaks and tempered winds and the pale green of olive groves. So sudden was the transformation that an involuntary exclamation of surprise ran through the train. The experiences of the past twenty years warn us that we must be prepared for similar surprises in the illumination that physical science is shedding on the world of nature. It seems to us that we are no longer walking by the light of the moon, but that the sun has already risen in its splendor. What shall the noonday be?

MATTER AND METHOD IN PHYSICS TEACHING.

BY R. H. CORNISH.

First Assistant, Wadleigh High School, New York City.

(Concluded from page 333.)

It is frequently urged that physics for culture should be something different in its scope and method from physics for college; that physics for those preparing for college should be different from physics for those not preparing. To my mind this distinction is unnecessary and unwise. Physics for college and physics for culture seem to me one and identical, just as geometry for college and geometry for culture are identical, both as to subject-matter and results obtained.

It seems hardly necessary to specify particularly the topics that should form the subject matter of a year's course in physics. Text-books published within the last year or two are as a rule smaller in volume than those published ten years ago. It seems as if authors were beginning to consider that not everything could be mastered in one science in one year and were inviting the criticism that they probably knew more than they had written in the book. I think a year's course should include the elements of all the great topics in physics, viz.: Mechanics of solids, liquids and gases, heat, light, sound, electricity and magnetism. I do not think it makes any great difference in what order these topics are taken up. It is conventional to place mechanics first and probably most schools begin with that subject, but I have obtained good results by beginning with light. In my present position I think light is a much more profitable topic for the girls than some others, electricity, for example. Prof. Tyndall speaks of the interest he aroused in his class by the problem: "How large a mirror placed against a vertical wall does a lady need in order to see her whole figure at one glance?" I can testify that this is still the favorite original problem at the girls' high-school. It lends itself very readily to home work.

Physics may be taught by text-book and recitation, by lec-

ture and demonstration, or by laboratory method. The judicious teacher in the secondary school will probably combine all these methods in varying amounts, as circumstances demand.

The text-book and quiz or recitation are indispensable for fixing the facts in the pupil's mind and helping him to word the expression of his ideas in clear language. But no good teacher at the present day would adopt this method exclusively. The study of a text-book of physics should be of great assistance, but the book will be very dry if the study of it is not enlivened and illustrated by the demonstrations before the lecture table. We frequently hear this method described as old fashioned and behind the times, and certainly no teacher would deliberately choose this method if another were possible, but it must be said that many successful physics teachers began their study of physics in this way, and under the inspiration of an enthusiastic teacher who had little or no apparatus, were able to obtain a fair knowledge of physical principles and laws. Joseph Henry, at the age of 15, entered the shop of a watch maker as an apprentice, although his chief ambition then was to excel as an actor and dramatic writer. Accidentally he came across *Gregory's Lectures on Experimental Philosophy,* the perusal of which created a love for science. Some have had even less than this. The ideal method will, it seems to me, combine the study of a text-book, accompanied by recitations, quizzes on the book, with explanations and demonstrations by the teacher and will include a certain amount of individual laboratory work. The pendulum of pedagogic practice has in the past swung from one side of the arc of method clear over to the other. A few years ago the favorite method in all sciences was that of the laboratory in which the student, under directions from the teacher, was set to rediscover the laws of nature. Text-book was abandoned and the student was expected to obtain his knowledge at first hand by the true method of asking questions of nature and very carefully listening to her answers. Conservative teachers soon found what might have been expected, that the untrained and immature mind could not rediscover nature's laws. The effort was attractive, but the result disappointing. Valuable as I consider the laboratory it must be confessed that unless very careful supervision is exercised a great deal of time is wasted in so-called

laboratory work, and this work is apt to degenerate into play, or from want of direction into aimless, discouraging and profitless effort on the student's part. The proper balance between laboratory work, recitation and demonstration is a most important question for the teacher to decide. The object of each part is the same, but the aim of each is different. The aim of the recitation is to discover how clearly the student has mastered the ideas, principles and laws which he has studied in the text-book, on the demonstration table or in the laboratory. The lecture and demonstration explain and illustrate those laws which the student cannot readily himself discover or illustrate. The demonstrations will often use more complicated apparatus than can be entrusted to the student or will illustrate qualitatively what the student will for himself undertake to discover quantitatively. The aim of the laboratory work is to make knowledge real and vivid in the experience of the student. In order to accomplish this purpose individual work by classes or in small groups is very desirable. There are several conditions in which laboratory work can not be done with success. First, if the classes which come to a teacher are so large and unwieldy that proper supervision can not be given, or if the room devoted to this part of the work is so crowded that pupils do not have elbow room in which to work satisfactorily, laboratory work becomes very difficult if not impossible.

I believe the laboratory work may be and ought to be the most valuable part of the physics course and no high-school that pretends to teach physics should abandon it. The conditions which temporarily might obtain that would make laboratory work impossible ought sooner or later to be rectified so that the pupil may have the satisfaction and pleasure of doing with his own hands, of sighting with his own eyes, of measuring and weighing with apparatus, which for the time is his own. From exercises carefully planned and done by the student himself there should come the highest satisfaction and greatest mental value.

What are the results of this method of laboratory work? Well, some of them are surprising. I asked a girl how to make a barometer. She replied (using the language of the book but omitting one word): *"First, take a bath."* The book said take a mercury

bath, which is the name of a flat dish for holding mercury. The answer seemed to amuse the other girls.

You remember that the forts of a sound wave or a wave of compression are a condensation or crowding together and a rarefaction or pulling apart of the air particles. When I asked this question of one girl her reply was: "A *condescension* and a *refraction.*"

An important detail of the laboratory work is the record which the student makes of what he does, or what he sees the teacher do on the lecture table. A laboratory note book properly attested is demanded by most of the colleges which require physics. The note book should contain a record of the object of the exercise, should enumerate the apparatus used, should contain the measurements and calculations made and a statement of the result finally obtained.

Laboratory exercises may be of three kinds: (1) Those whose object is the verification of a law. The law has presumably been learned from the text-book or the teacher. Typical of this class may be mentioned the laws of accelerated motion and the laws of the pendulum. (2) Those exercises whose object is the determination of a physical constant. Determinations of specific gravity, of specific heat, the coefficient of expansion of a metal rod, of the coefficient of friction between two surfaces, of the index of refraction, of the relative resistance of different kinds and sizes of wire, all illustrate problems of this sort. (3) Exercises whose object is the discovery and statement of a law. Of this sort may be mentioned Archimedes' Law, the law of flotation and the law of the reflection of light. These exercises must have simple results or the teacher will find that inevitably the result must be told to the student. In exercises of the first and third class we have the opportunity to illustrate the difference between inductive and deductive physics teaching. Exercises of the third class are inductive. The student performs the exercise not knowing the result. The exercise may be stated in the form of a question, thus: "What relation exists between the weight of a floating object and the weight of the water displaced," or "What is the size, position, appearance and kind of image formed by a plane mirror?" In these cases the pupil can be carefully led to

formulate the law from the results of his laboratory work and thus the teaching may be truly inductive. In exercises of the first class the process is deductive. The pupil is told, or has learned, the law and his laboratory work consists in verifying it. For example, to derive the law of the inverse squares in light by an inductive process is possible, but seems to me a waste of time. It is certainly quicker, and in the end, I think, just as effective, to state the law and then illustrate it by the lantern. In the conduct of laboratory work two methods are in common use. These I may call the class method and the individual, or group, method. In the individual method each student, or group of two (rarely three), is given a problem to work out experimentally with apparatus specially set up for the purpose. The laboratory may contain ten or a dozen different sets for the solution of as many different problems. Each group has a different problem. Generally printed directions are attached to each set, telling the pupils what to do. The teacher must have explained the nature of the exercise and something of the method of manipulation. One or more laboratory assistants, dependent upon the size of the class, are needed. This method, which is used in many high-schools, has always seemed to me to be essentially a college method, and ill adapted to secondary schools and immature pupils. The class method of laboratory work requires duplicate apparatus. Separate pieces must be provided for each pupil or each small group. By this method the whole class can be led by direction, question and suggestion to the desired result. After the exercise has been performed a class discussion can be held while the problem is still fresh in the student's mind. These exercises are, with two or three exceptions, quantitative in character. The lecture table demonstrations, on the other hand, are mostly qualitative. They are the outcome, in my case, of 15 or more years' experience and of experimenting with different methods. Quite recently this whole procedure has been called in question by a high authority. I refer to Pres. G. Stanley Hall.

In an address before the N. E. Association of Colleges and Preparatory Schools, and repeated substantially before the Conference of Educational Workers in New York, he said: "Boys of this age [the middle teens] want more dynamic physics. Like

Maxwell when a boy they are interested chiefly in the 'go' of things. Those with aptitudes for physics want and need wide acquaintance first, with tops, kites, and other physical toys, then with clocks, dynamos, engines, machinery, with some experience in running it and using tools; in looking into ,taking apart and putting together almost anything that will go. Moreover, exactness comes relatively late in the development of the youthful mind, as it did in that of the race, long after interest in general principles and especially forces. The normal boy of the middle teens is often a walking interrogation point about ether, atoms, nature of electricity, X-rays, motors of many kinds, with a special gravity of mind toward frontier questions, where the great masters know as little as he. He would like to see hundreds of demonstrative experiments made in physics, and the liberty to repeat most of them himself without being bothered about mathematics. Moreover, he has a veritable passion for brief stories of great men. The heroology of the history of physics, if rightly applied, might generate a momentum that would even take him through the modern course. He is essentially in the popular science age. He wants great wholes, facts in profusion, and very few formulæ."

Now Pres. G. Stanley Hall is a thoughtful man, and such an utterance as that just read requires careful examination. It amounts to a condemnation of quantitative work, such as has been slowly elaborated and adopted in many of our high-schools. That kind of physics teaching known as "Harvard Physics" is criticised. There are several points in this quotation which every physics teacher can take to heart and profit by. (1) Qualitative or demonstrative experiments should be used freely by the teacher. To this I have already alluded. They are indispensable to the proper presentation of the subject. Under suitable direction and careful guidance some of these demonstration exercises may become profitable laboratory exercises. But I think it is true, as pointed out by Prof. E. H. Hall, of Harvard, that "qualitative facts are apt to be very obvious or very obscure. A stone falls to the ground. Everybody knows that. Why does the stone fall to the ground? Nobody knows that. How fast, under what quantitative law, does the stone fall? That is the kind of question we can take up in the laboratory with the least likelihood of wasting time and effort,

although that particular exercise is too difficult for ordinary school laboratories." (2) The great names in the history of physical science should be more frequently referred to, and their contributions to our knowledge should be explained. I think this is commonly neglected. The history of physics cannot be formally taken up nor should it be, but the pupil should at least know the names of Archimedes and Galileo, of Newton and Pascal, of Franklin and Henry, of Faraday and Tyndall and many others, whose names are immortal. (3) The use of simple tools should be encouraged and also the desire to understand the mechanism of the machines which come before the pupils. But to attempt to substitute the workshop for the laboratory would, in my judgment, be a serious mistake.

As was to be expected, the criticism on physics teaching was not allowed to pass unchallenged. President Eliot replied that the results of the kind of physics teaching which had been encouraged and insisted upon by Harvard University had been quite satisfactory to the university authorities and that the work done by the schools was improving each year. He also said that one great aim of physics teaching was training the observational powers of the pupil and that quantitative laboratory work was much better for this purpose than any other kind.

But the most complete defense of the quantitative method and criticism of the method urged by Pres. Stanley Hall that I have seen was made by Prof. E. H. Hall, of Harvard University, in an address read before the Physics Club of New York and published in School Science (Vol. II, p. 57). This very interesting address is entitled "The American Physics Teacher's Opportunity."

What shall be said of the qualifications of the teacher of physics? They are exactly the same as the qualifications of the successful teacher of any other branch. A thorough knowledge of the subject and of related subjects, a patience never failing, an instant readiness to appreciate the pupil's difficulties and to put yourself in his place, and tact in winning and keeping the pupil's confidence—these are the necessary requirements for the physics teacher or for any teacher. One thing the physics teacher needs in preëminence—the willingness to spend an enormous amount of time in the endless detail of experimentation. Slipshod experi-

ments, efforts that do not succeed, produce a bad impression and weaken the respect of a class for a teacher. The art of experimenting must be learned by repeated, careful and long continued trial. But the results of this repeated effort will more than repay the teacher. We have had recently in Montclair, N. J., an evening devoted to Modern Heroes. The heroes whose deeds were exploited and who were held up to our admiration were the firemen of New York City and the members of our government life-saving service, which extends its operations along our ocean border. How our hearts thrilled as Mr. James Sheffield, one of the fire commissioners of New York, and Major Piper, of Washington, told in simple language, story after story of the deeds of noble daring and heroic life-saving effort made by the firemen and the surfmen in their regular line of duty. Now in comparison with such lives as these how tame and uneventful must seem the life of the teacher. How often have I wished that I was engaged in some business in which I could have immediate and ocular evidences of the results of my work, such as a carpenter or a paper-hanger has. But such is not the case. The results of the teacher's labors are found in the mental and moral improvement of the pupil. Quick returns from mental investments made by us in others we very rarely have. If, however, we can see a slow but sure growth, a steady but sure increase in mental power, and chiefest a moral growth by which the boy or girl gives evidence of becoming more patient, more thoughtful, more self-controlled, we may rest in a measure satisfied. Your pupils will soon forget the physics and mathematics and Latin which you teach them, but if you have been master of the subject and of them, have been patient, interested and devoted, they will never forget *you*.

How have our own teachers influenced us? I think in two different ways. First, by quickening our enthusiasm in some branch of study by their own enthusiastic devotion to it. How vivid and delightful is the memory of the geological excursions we took with old Prof. Dana, then 70 years old! At that age he was still the leader of the boys in climbing hills and rocks and in leading his pupils to places where he found material to illustrate his geological story. But secondly, and more important, our teachers have impressed us by the unconscious influence of their lives and character.

"After all," says Gilman, "a great teacher is not to be measured by his learning but by his example."

The life of the scholar and teacher may not be exciting and eventful, but in its dignity, its serenity, it may leave little to be desired. As I think of Dana and Porter and Woolsey and Newton, the thing that impresses me most is not their learning, although that was great, but their simplicity, their elevation of soul, their sweetness of spirit, their purity of life. Happy the boy or girl who comes under such influences and who profits by it! Happier still that teacher who can worthily exert it!

THE THEORY OF ELECTROLYTIC DISSOCIATION.

BY LOUIS KAHLENBERG, PH. D.

Professor of Physical Chemistry, University of Wisconsin.

The teacher of natural science is frequently confronted with the question as to how much prominence should be given to this or that scientific theory. It is well recognized that theories are the changeable, the ephemeral part of science; that they are really only tools by means of which the truth, the facts which are eternal, may frequently be discovered, unearthed, and temporarily correlated. Facts carefully established by experiment and observation, and gathered together in the form of carefully made general statements become verbal expressions of the laws of nature. These generalizations so reached are the real treasures of science; they constitute the solid stones of which the temple of science is built; and it is through these that science serves mankind in the broadest and highest sense of the word. It is clearly very essential that the teacher should at all times distinguish very carefully between what is hypothesis and what is fact. The latter once carefully established stands firm and unchangeable, while the theory is only useful in so far as it enables one to group known facts together and to discover new truths. As soon as a theory becomes inadequate

to do this, its period of usefulness is over and its doom is sealed. The pathway of the progress of science is strewn with defunct theories and hypotheses. The spectacle of the birth, growth and death of scientific theories often appalls the less thoroughly versed, for they see in it, as they fancy, the instability of science. Much of this misconception would soon disappear if teachers would always insist that their pupils distinguish at all times between facts and opinions or assumptions, and never for a moment elevate the latter in their minds to the dignity of the former. In this attitude of mind toward fact and theory the teacher of science must ever lead by strong force of example, if he would truly succeed in his vocation, and especially if he would seek during his spare hours to add something of value to the sum total of human knowledge. The one who becomes so imbued with a theory that he raises it in his mind to the dignity of a fact is sure to fall into serious errors; for while hypotheses frequently aid the investigator by stimulating inquiry and by suggesting new relations and new ways of doing things, they also very often by their equally strong hints that such and such things are impossible stifle inquiry along certain lines, prevent new discoveries from being made, and so become a real bar to true progress. However, the investigator who ever bears in mind the difference betwen facts and theories is not in the least worried by the continual coming and going of the latter; and the teacher of science who leads his pupils to distinguish between established truths and hypotheses need have no apprehension that he has misled his pupils by acquainting them with a theory that soon after has to be entirely discarded. Yet it is true that it is best not to bring to the notice of students—at least of students of high school grade—scientific theories that have not a broad foundation of facts to stand upon, or theories of which it is evident at the time of instruction that their period of usefulness is practically over.

There is practically no one theory of chemistry that has attracted more attention in the last fifteen years than the theory of electrolytic dissociation proposed by Arrhenius in 1887. Though far from universally accepted, it still has many ardent adherents. This theory is so well known that it is entirely unnecessary to give its purport or its history here. It will be recalled that the

hypothesis is based primarily upon the claims of Arrhenius that the molecular conductivity of many solutions (that had been measured at the time of the promulgation of the theory) increases with the dilution; that substances which when dissolved conduct electricity also have "abnormally" low molecular weights in such solutions when tested by freezing- or boiling-point methods; and that the so-called degree of dissociation may be calculated from the electrical conductivity or the results of the molecular weight determinations. In his original paper Arrhenius stated that the phenomena of electrolysis, when viewed in the light of thermodynamics, require the assumption of free ions as was pointed out by Clausius, and that the heats of neutralization of acids and bases in dilute solutions, and the various physical properties of salt solutions, which are well known to be, in general, additive in character, support the electrolytic dissociation hypothesis. Through the latter it was sought to gain for the van't Hoff theory of solutions a general application, and at the same time to bring into correlation facts that had hitherto been entirely isolated. Inasmuch as the commonly used aqueous solutions of acids, bases and salts are electrolytes, practically all the well known chemical reactions of neutralization, precipitation by double decomposition, etc., many of which occur instantaneously, were soon viewed as taking place between the so-called free ions. Books explaining chemical changes and changes of solubility on the ionic basis were soon published; of these Ostwald's *Scientific Foundations of Analytical Chemistry* was the most prominent one, from which ideas were taken, modified, elaborated and incorporated into more elementary texts. The claim was even made that the chemistry of atoms and molecules has given place to the chemistry of ions, and that chemical affinity is a back number.

In the face of the enthusiasm shown by adherents of the dissociation theory and the voluminous material they have published, it is no wonder that teachers are often made to feel that they are entirely behind the times, unless they teach their chemistry with the theory of electrolytic dissociation as the back bone of it, and in general explain the chemical, physical and physiological behavior of solutions from the standpoint of the dissociation theory. But the teacher of the secondary school was not alone

in this, university professors and other investigators of note in physics, chemistry and physiology were looked at askance and even pitied because they could not see what Lothar Meyer called "das wilde Heer der Ionen," and follow them in their gambols.

There are now at hand abundant well established facts that show that the theory of electrolytic dissociation is entirely inadequate, in reality untenable. To rehearse all these here in detail is entirely impossible; they have been fully presented from time to time in a series of articles in the *Journal of Physical Chemistry,* and to these the reader must be referred. In summary, it has been shown that instantaneous chemical reactions, solubility changes, and coloration changes (comparable in every way with those that take place in the common aqueous electrolytic solutions) occur in solutions that are most excellent insulators. On the other hand, the presence of electrolytic conductivity has been found to be by no means necessarily accompanied by chemical action. (Compare the recent article by Kahlenberg and Schlundt on the behavior of solutions in which liquid hydrocyanic acid is the solvent, *Jour. Phys. Chem.,* Oct., 1902.) Thus chemical action takes place quite independent of electrolytic conduction; and, again, the explanation, that, for example, the chlorine in such compounds as chloroform can not be precipitated as silver chloride because the chlorine is not in the ionic state, inasmuch as chloroform is not an electrolyte, is clearly no longer valid. Of this the reader will be convinced by referring to my article in the January number of the *Jour. Phys. Chem.,* 1902. Furthermore, so-called abnormally low freezing-points or abnormally high boiling-points of solutions are by no means always accompanied by electrolytic conduction; while normal freezing-points, normal boiling-points or even abnormally high freezing-points and abnormally low boiling-points are frequently exhibited by solutions that are electrolytes. Again the molecular conductivity does not always increase with the dilution. These statements are true of aqueous as well as of non-aqueous solutions. It is therefore clear that the dissociation theory is no longer tenable. It has become untenable because further investigations have furnished facts that are chemical, physical and physiological in character showing how very inadequate the theory is. With the downfall of the Arrhenius hypothesis, the

original difficulty with the van't Hoff theory of solutions recurs. The latter hypothesis is based upon the analogy between gases and solutions, and is practically inseparably connected with the Arrhenius theory. No doubt these theories have done much toward stimulating research in chemistry and physiology and due credit should be given them on this account. The theory of solutions has, however, directed attention exclusively to dilute solutions. It has thus stood in the way of the study of more concentrated solutions and so has in reality unquestionably been a drawback to true progress toward a thorough understanding of the very important subject of solutions. Similarly the Arrhenius theory has directed particular attention to the phenomena in dilute solutions. The *facts* known at present are sufficient to warrant the expression of the opinion that for a true conception of the nature of solutions and of electrolytic processes it is extremely unfortunate that work should have been directed thus almost exclusively toward dilute solutions.

The act of solution itself is undoubtedly caused by a mutual attraction of solvent and solute, which attraction depends upon the individual nature of the substances under consideration. This mutual attraction is very closely allied to, if not essentially identical with, what is commonly called chemical affinity. This attraction is the so-called osmotic pressure. In the careful study of the act of solution, and of the physical, chemical and physiological properties of solutions nothing becomes more evident than that chemical affinity between solvent and solute really determines all these phenomena. Chemical affinity then should be brought to the forefront in the study of solutions rather than relegated to the background. As for the electrolytic conductivity of solutions, no one can tell whether a given solution will conduct electricity or not without actually trying it. The Arrhenius theory claims to be able to make such predictions, but the facts show that it is entirely unable to do so. We have at present no adequate mechanical explanation of the process of electrolytic conduction; and this is not astonishing, for we also have no such explanation of the conduction of electricity in a wire. It is quite probable that we shall eventually find that these two phenomena are much more intimately related to each other than they seem to be at present.

Moreover, as Fitzgerald said so well in his celebrated Helmholtz memorial lecture, it is not to be charged against any one that he is unable to explain all the phenomena of the universe. The general course that should be pursued in the further study of solutions, I have indicated in the *Jour. Phys. Chem.*, June, 1901.

In being gradually outgrown by the multiplication of facts that are not in harmony with it, the theory of electrolytic dissociation has simply followed the natural course that all scientific hypotheses, founded upon too narrow a basis of induction, must eventually take. Nor need it cause a pang of regret or a sigh to see a worn-out theory go, even though a new one is not at once at hand to supplant it. The older and the more perfect a science is, the fewer theories it has. At any rate, investigations bringing facts that undeceive us as to the real adequacy of a theory, always represent a true step forward; they are always to be welcomed.

The teacher who has not hitherto seen fit to bring the theory of electrolytic dissociation to the notice of his pupils, certainly has no good reason for doing so now, for he can not be classed as being behind the times if he omits mentioning the theory. On the other hand, he who has given his instruction entirely or in part by means of the theory should study with care the new facts that are at hand; should bring these before his pupils, who will not be slow to recognize that the theory is unable to stand in face of the facts. Above all, let the pupils repeat the experiments and then draw the conclusions that follow directly from them. Thus they will learn to love and conserve the truth though theories may fall, and they will at least in a measure experience what the great Scheele did, when he said: "es ist ja nur die Wahrheit, welche wir wissen wollen, und welche Freude bereitet es nicht sie erforscht zu haben."

THE COCOANUT—ITS COMPOSITION AND GERMINATION.

BY J. E. KIRKWOOD.

Instructor in Botany, Syracuse University.

It is not strange that some of our most common articles of commerce should yield some very interesting facts when properly investigated, and the cocoanut is one of these. Probably every one knows the general characteristics of this fruit, and some may know its value as a food and the particular nature of its food content. Some recent investigations,* however, have shown that such knowledge as we have is in the form of rather fragmentary information contributed from various sources. Inasmuch as the cocoanut is not a native of these latitudes and is cultivated only in conservatories, some of the very interesting features of its early growth are also entirely unknown to many. The investigations, the results of which are given in the paper just cited, were undertaken with a view to determining the nature and quantity of the food content of the fresh nut and the manner and extent of its utility to the young seedling.

It is a matter of common observation that the meat of the cocoanut contains much fat. In the manufacture of the commercial cocoa-oil this is obtained by pressure or by other mechanical means. In the fibrous residue from this process there is still some of the fat left, hence it is evident that one cannot by this means come by a knowledge of the exact percentage of fat in the meat. If, however, the tissue is ground to a pulp and then placed in some solvent of fat, preferably ether or benzine, by proper manipulation even the last trace of the fat may be removed, and, knowing the weight of the raw material and the extracted fat, after evaporation of the solvent, its percentage may be obtained by a simple calculation. By this means we obtained from the fresh meat of the nut 37.29 per cent of substance soluble in ether, which may, of course, contain traces of other bodies besides fat.

(*) Kirkwood & Gies, Chemical Studies of the Cocoanut with some Notes on the Changes during Germination. *Bull. Tor. Bot. Club.* **29**:321-359. June, 1902.

The solid residue of the tissue, which had been thus treated, was freed from ether by evaporation, and placed in a ten per cent solution of common salt and allowed to stand, with occasional agitation, for a day or two; the proteid bodies, at least the most of them, were thus removed. The salt solution, after filtering, was placed in a bag of vegetable parchment and hung in running water. As proteid bodies not affected by digestive agents are indiffusible, they remained in the parchment vessels after all the salt had diffused out, which took sometimes several days. The contents of the vessel were then removed and the proteid which had been partly precipitated by removal of the salt was separated by filtration and the filtrate heated and treated with chemicals to remove whatever proteid remained. Details of the process need not be described here, as the methods are those given in some of the laboratory manuals in botany.† This treatment yielded 4.08 per cent of albuminous substance.

As to the presence of sugars and other soluble carbohydrates, it was found that the fresh meat of the nut or endosperm contains about 7.9 per cent. Both cane sugar and grape sugar are present, but the exact quantity of carbohydrate is probably not expressed in the figure given above, as they were not especially investigated and the expression of the approximate quantity was obtained by subtraction. Other non-nitrogenous substance is probably included in this as well. The fresh meat contains 46.31 per cent water and 52.69 per cent solid matter. The solids besides including the substances already named contain 1.03 per cent of mineral and 3.39 per cent of fibrous matter. Among the mineral substances present are found usually silica, iron, aluminum, calcium, magnesium, potassium, phosphorus and sulphur. The percentage figures given above were the averages of many different determinations made both upon fresh nuts directly imported from Jamaica and upon nuts from the market in New York city. It will be seen from the figures given that the cocoanut is a very nutritious article of diet. Nearly fifty per cent of the weight of the fresh meat is food in the ordinary sense of the word, that is, proteid, carbohydrate and fat. The milk of the nut contains 4.77 per

(†) MacDougal, *Practical Text Book of Plant Physiology*. Ch. IX. Longmans, Green & Co. 1901.

cent of solids, of which 0.56 per cent is mineral substance, and 4.21 per cent is organic (carbohydrate, fat, etc.). Only traces of proteids are present; fat may be seen floating about in small globules if a drop of the milk is examined under a lens. Sugar forms the principal part of the solid matter. The fresh milk is slightly acid, due to the presence of acid phosphate. Both alkali and earthy phosphate are present, and the latter can be precipitated, in part at least, on boiling. Evaporation of the milk to a small bulk by heat produces a dark colored, molasses-like substance from which cane sugar crystallizes on cooling.

As the cocoanut comes to our markets it is deprived of its husk. This husk is of a coarse fibrous structure and covers the nut so thickly that in its original form the fruit is broadly oval, the nut occupying an eccentric position with the "eyes" directed toward the stem end of the fruit. In its natural habitat the cocoa palm grows abundantly near the water and as the fruit falls from the tree it often floats about until it comes to rest in some shallow place and there germinates. The husk not only makes the fruit lighter, but probably serves under any condition by virtue of its absorptive quality to keep the seed more moist and so facilitate germination. Many of the nuts imported in the husk for our work were germinated by keeping them about half covered with earth, saturated and at tropical temperature.

The germ of the nut is to be found under one of the so-called "eyes" at the end. The longitudinal ridges separate the hard coat into three parts, which evidently were once the three parts of an ovary which bore three seeds, one for each division or carpel. The seeds have become reduced to one, which fills all the space within the hard shell which is in reality a part of the ovary wall. The fertile carpel may be detected as the one lying in the largest angle formed by the divergent ridges at the end of the nut.

When the nuts are kept under proper cultural conditions for about three months the first signs of germination will be evident by the appearance of the shoot through the husk above and the roots below. By this time the germ, which is in its resting condition cylindrical and lying perpendicular to the surface of the nut, has elongated and pushed its inner end into the cavity of the nut and the other end outward. The outer end develops the

stem and roots. The inner end expands into an oval body which ultimately, after about ten months, fills the entire cavity. This expanded inner end is the cotyledon which functions as an absorbing organ. Wherever this cotyledon comes in contact with the meat of the nut it softens, dissolves and finally absorbs it. The surface of the organ is covered with villiform structures and corrugations which give it much the appearance of a stomach turned inside out, and as far as function goes that is just what it amounts to. Wherever the endosperm has not been attacked by the cotyledon it remains as palatable as ever and apparently unaltered.

This process of digestion proceeds by means of ferments or enzymes. In any digestive organ, animal or vegetable, the transformation of insoluble and indiffusible proteid, carbohydrate, or fat into a soluble and diffusible form is accomplished by means of enzymes. It is often possible to separate these ferments from the organs or cells which produce them and to demonstrate their activity upon foods when thus separated. For example, the active principle of yeast may be separated from the yeast cell; the starch-digesting diastase found in many seeds has long been in use for various purposes. But enzymes are often found mixed with the food material in resting cells where the special digestive organ either is or is not present, and it becomes active only when conditions are right for germination. A common means of extracting the enzyme is to cover the finely divided tissue with water and allow it to stand for several hours. The water is then filtered and the enzyme precipitated by adding several volumes of alcohol. The precipitate may be separated by any convenient means such as filtering and dried. It is active, however, only when in solution. The presence of an enzyme may be detected by watching its action on starch paste, fibrin, fat or substance taken from the tissue in which it is found. In the cocoanut the cotyledon shows a very active enzymatic action. The study of this particular seed in its germination is instructive, both from the morphological and physiological point of view. The transformation of the fat of the meat into starch takes place, and this is readily evident to the investigator, although there is no starch in the meat, but during germination there is much of it to be seen in the cotyledon. Proper tests on microscopic sections demonstrate the presence

of fat in the outermost layer of cells of the cotyledon and the absence of starch there; likewise the presence of starch in the inner tissues and the absence of fat.

The food reserve in the cocoanut lasts about a year after germination has begun. During this time the plant gets much of its nutriment from the soil and the air. The proportion of water diminishes from the cotyledon to the tips of the leaves and there is a corresponding increase in the amount of solid matter. The substance of the cotyledon, the stem and the roots, contains much more mineral matter than is to be found in the endosperm and the leaves. The problems of nutrition in this plant which are suggested by these observations have not yet been attacked, but they will no doubt afford some very interesting facts at some future date.

THE EUROPEAN EDIBLE SNAIL.

BY M. A. BIGELOW.

Department of Biology, Teachers' College, Columbia University, New York.

The value of the European edible snail (*Helix pomatia*) for observation on the living animal, as well as for anatomical study, deserves to be more widely known to teachers of biology and nature study than appears to be the case at present. I know of no animal which is at once so available, so easily kept living in the laboratory until needed for class work, and so interesting to pupils of all grades. These snails are now regularly imported from France and Germany, and may be found in the provision markets of the large cities during the cooler months, *i.e.*, from about October 15 to April 1. In New York they may be ordered from C. Perceval, dealer in table delicacies and fine provisions, 100 Sixth avenue. They usually cost about $1.25 per hundred. The Brooklyn Biological Supply Co., 333 Halsey street, Brooklyn, supplies them in small quantities. Less than two dozen in a package may be sent by mail.

These snails are brought from Europe in the dormant or winter condition, the aperture of the shell being sealed by the temporary plate (epiphragm) of calcified mucus. In this condition they may be packed, shipped, and stored for months in dry sawdust or "excelsior." The snails may be purchased in autumn and the stock kept in some *cool, dry* place until they are wanted for class study, perhaps in late spring. When active snails are needed, it is only necessary to put them in a warm, wet place on grassy sod, moss, sand, or sawdust; under the influence of the moisture the epiphragm soon softens and the head and foot emerge from the shell. The emergence may be hastened by first removing the epiphragm.

The active snails may be kept so for months in a simple vivarium which consists of a shallow box or bucket covered with coarse wire netting and having the bottom covered with grassy sod or coarse sand. I prefer the sand because it may be washed in running water occasionally, which is desirable in case the vivarium is kept in the school room. The snails may be fed with lettuce, cabbage and other vegetables.

Perhaps the most convenient way to handle the living snail in the class-room is to allow it to crawl on a plate of glass to which the foot soon firmly adheres. All external parts and movements are then easily seen from any desired point of view. Lettuce leaves may be placed near the mouth and the process of feeding observed through the glass; and in the same way the remarkable muscular movements of the foot may be seen. If the snails are sluggish when wanted for class study, stimulate them by repeated dipping into lukewarm water.

These snails are best killed for anatomical study by drowning in water which has been boiled to expel the air and kept tightly covered until cooled. Then put the snails into the water, cover tightly, and after about thirty hours they will be found more or less stupefied in an expanded condition. Select those which are quite stupified and place them one by one in water heated as hot as the hand will bear, quickly smooth out wrinkles in the foot, press upon the bases of tentacles to extend them, and having arranged the parts as natural as possible, drop the animal into 5 per cent formaline. With a little practice 80 per cent of the snails can be killed and hardened in a very life-like condition of expansion. After

hardening for a few days in the formaline, the visceral mass of some individuals may be easily twisted out of the shell, but usually the columellar muscle clings so firmly that it is necessary to chip the shell with forceps in order to remove it.

A METHOD FOR COLLECTING AMOEBAE.

BY S. O. MAST.

Department of Biol. Science, Hope College, Holland, Mich.

Amoeba is an animal of such vital importance in the study of biology and so difficult to collect in numbers large enough for class use, that, I trust, anything that may be said to facilitate their collection will be of interest to readers of SCHOOL SCIENCE.

Until this year in collecting amoeba, we simply scraped the surface ooze from the bottom of a spring hole near our college laboratory, with a small net of coarse cotton, and put it into pint fruit jars. In working with such collections, it was noticed that as soon as the ooze settled amoebæ were found on or near its surface; consequently it was thought that if taller vessels of the same capacity were used so as to make the surface of the ooze in them comparatively smaller, the animals would be found in proportionally larger numbers. In order to test this idea, ooze was collected in pint jars and after it had thoroughly settled, the surface of the ooze in the jars was lifted with a large pipette and put into test tubes and again allowed to settle. In this way amoebæ were concentrated to such an extent that as many as fourteen were found in a single drop taken from the surface of the ooze in the test tubes, while usually several drops taken from the surface of the ooze in the jars had to be examined to find a single animal.

If the animals are not to be used at once, it is well to put a few fibers of spirogyra or some other aquatic plant into each test tube. By so doing amoebæ were kept in good condition for over a week.

TUBERCULOUS SPUTUM IN PUBLIC STREETS.

BY W. H. MANWARING.

Johns Hopkins Medical School, Special Lecturer in Hygiene, Eastern Illinois State Normal School.

Dr. H. E. Annett has recently published the preliminary results of an experimental inquiry he is making as to the prevalence of the germs of tuberculosis in sputum taken from the public sidewalks of Liverpool.* His results are so striking that they cannot fail to impress even the most elementary student of public hygiene.

His paper opens with a brief review of the most important facts bearing on the hygiene of tuberculosis. He calls attention to the controversy now going on as to the relation between the human and the bovine forms of the disease, and says that, although authorities are as yet not agreed as to what this relation is or what the danger from tuberculous cattle may be, they all agree with KOCH that "human sputum is the main source of human tuberculosis."

Infection from such sputum takes place, he says, most readily in over-crowded and ill-ventilated dwellings, workshops, and rooms, but may come from its inhalation in public places in the form or dust, or from its introduction into our homes on boots, shoes, and skirts. His inquiry is to determine how great these latter dangers really are.

Tubercle bacilli outside the human body are subjected to many conditions unfavorable to the life of micro-organisms. Among these are drying and the action of sunlight and of putrefactive agents. Experiments show, however, that these germs are very hardy. They withstand drying for over six months and resist putrefaction and sunlight for long periods of time. There is even evidence that under favorable conditions they may actually multiply in sputum outside the human body.†

---

* The Thompson Yates Laboratories Reports (Liverpool), Vol. IV (1902), p. 359

† Sternberg, Manual of Bacteriology, p. 381.

The demonstration of tubercle bacilli in consumptive sputum is a comparatively simple matter. It is based on their staining characteristic. Their chemical structure is such that, by proper methods, they can be colored bright red, while other bacteria likely to be present in human sputum, are stained blue.

This is the usual test for these germs, but is not an absolute proof of their presence, because there are a few rare bacteria, e. g., the bacillus of leprosy, that give the same reaction. The strict demonstration is obtained, therefore, only by inoculation methods. A guinea pig inoculated with tuberculous material will develop tuberculosis and ultimately die of the disease. A microscopic study of properly stained sections of its tissues will then show typical lesions swarming with tubercle bacilli.

Dr. Annett collected 108 specimens of sputum from the sidewalks of Liverpool, mucous, muco-purulent and purulent accumulations being taken indiscriminately, only the most liquid ones being neglected. From each specimen he made two smears on cover glasses, and with portions of each he inoculated two guinea pigs.

The results of his study up to the date of publication are as follows:

1. A microscopic examination of the stained cover glass preparation showed probable tubercle bacilli in three of the specimens.

2. In five of the inoculation experiments, both animals died of general tuberculosis.

Five of the 108 specimens, therefore, contained virulent tubercle bacilli, though in two of them not in sufficient numbers to be readily found microscopically. Practically 5 per cent, one-twentieth, of the mucous, muco-purulent and purulent expectoration on the sidewalks of Liverpool are, therefore, tuberculous, and, consequently, a menace to public health.

The number of such sputa daily deposited on public sidewalks can be inferred from the fact that, in a slow walk of one hour along the principal streets of that city, Dr. Annett counted 183 such accumulations. When we take into account the rapidity with which sputum dries, is ground into the dirt, or swept up by trailing garments and thus rendered invisible, we realize that

this number gives but a faint idea of the extent to which objectionable expectoration is going on, and, consequently, of the extent to which pedestrians are subjected to infection by tubercle bacilli.

Dr. Annett believes that the dangers from such expectorations can be overcome by the following means:

1. By educating the public to an understanding of the dangers from such sputum.

2. By passing laws regulating expectoration in public places.

3. By daily washing and cleansing the sidewalks of the principal streets.

He commends the efforts already made in the United States to overcome these dangers and quotes the laws relative to the matter now in force in Baltimore, New York and other of our eastern cities. He closes his article with an appeal for similar legislation in England.

Those, however, who have watched the almost futile attempts of legislation to overcome this evil in our larger cities, cannot escape the conviction that to his first and third means only can society look for relief. And of these, education is the more important, as it is the necessary foundation for all other means.

This education should include a first hand knowledge of the main facts bearing on the hygiene of tuberculosis,* an understanding of the predisposing factors of the disease,† and a familiarity with the results of the modern methods of treating it.‡ It can be given to advantage only in the public schools. To it, and to the public school teacher in particular, must society look for help in banishing the "great white death." As Dr. Knopf so strikingly says, "to combat consumption successfully requires the combined action of a wise government, well trained physicians, *and an intelligent people.*"§

Are the public school teachers doing all they can to create this wide-spread intelligence on which the government and the physician must build?

---

* Abbott, Hygiene of Transmissible Diseases, p. 112.

† Bergey, Principles of Hygiene, p. 25.

‡ Hiller, Tuberculosis, Its Nature, Prevention and Treatment. (Cassell & Co., London and New York, 1900), Chapter VII, p. 157.

§ Knopf, Tuberculosis, a Disease of the Masses and How to Combat It. (The International Prize Essay of 1900; M. Fierstack, Publisher, N. Y.), p. 86.

Metrology.*

SYSTEM IN METRIC WEIGHTS AND MEASURES.

Now that people are making some use of metric weights and measures in this country it is of interest to notice what is the essential characteristic upon which the superiority of the system depends. The advantage of relations between different kinds of measure is not generally appreciated among the people of the United States because of their lack of past experience of such simplicity; as paintings are not appreciated by the blind, or music by the deaf. To make our people recognize the advantage of simple relations, one course is to point out what little relationship is still to be found connected with our old weights and measures and is therefore comparatively easily understood; for many of them are surviving fragments of what were originally systematic arrangements.

It has been the usual plan to have coinage related to weight. There used to be in England a silver coinage of which 240 pence made a money pound, and there used to be a pound weight and a penny-weight as heavy as the corresponding silver coins. Even after various changes had been made, if silver, or any other material, was worth a fraction of a penny per pennyweight, it was worth the same fraction of a pound sterling per pound troy. The correspondence of the names made it easier to keep the association in mind. The relation in question dated from a thousand years ago. The monetary reckoning was established by Charlemagne and spread over the principal countries of Europe and America. The weight was derived from the Roman Empire of 2,000 years ago, where they used the Roman numerals, such as we see on old clock dials, tombstones, etc., so that subdivision into twelfths was not open to the objection that it is here now. The twelfth of the pound was called ounce, from the Latin word, *uncia,* meaning originally one-twelfth part of the monetary unit, but having its meaning extended to one-twelfth of any unit.

* Communications for the Department of Metrology should be sent to Rufus P. Williams, North Cambridge, Mass.

It was used for a twelfth of the unit of liquid measure and for a twelfth of the unit of land area; and from its meaning the twelfth of the foot we have our word *inch* also. This was systematic to some extent. In countries that inherited the Roman civilization something near the Roman inch and foot, and for medicinal purposes something near the Roman weight, continued, with numberless minor variations in value, down to about a century ago, along with 12 pence in the shilling; but these things have been abandoned almost everywhere.

For another illustration of lost connections, the apothecaries in Great Britain and the United States used to have measures and weights corresponding, thus:

$$\left.\begin{array}{r}\textbf{A fluidounce,}\\ \textbf{containing 8 fluidrachms,}\\ \textbf{each of 60 minims, or drops}\end{array}\right\}\ \textbf{and}\ \left\{\begin{array}{r}\textbf{an ounce (Troy),}\\ \textbf{of 8 drachms,}\\ \textbf{each weighing 60 grains.}\end{array}\right.$$

These names and ratios gave obvious simplicity, which had its value even when the measures had been made to hold weights a little different from those indicated. They emphatically called attention to the relation between capacity measure and weight of water contained, which has been the ideal of the most widely separated times and places. The old saying was "A pint's a pound the world around." For a succinct statement as to ancient connections in England, the following passage may be quoted from the celebrated *Lectures on Natural Philosophy* (1807) by Dr. Thomas Young, who was subsequently one of the Commissioners of Weights and Measures. Referring to Phil. Trans. 1740, p. 457, he said:

"Mr. Barlow supposes that the ton measure of water contained originally 32 cubic feet, and weighed 2,000 pounds, which was also called a ton weight, the gallon being somewhat smaller than it is at present, and the cubic foot weighing exactly 1,000 ounces, or 62½ pounds. A quarter of wheat weighed about a quarter of a ton, and a bushel as much as a cubic foot of water. A chaldron of coals was also considered as equivalent to a ton, although it now weighs nearly half as much more."

The notable points are that simplicity of relation was a primary consideration, but has not survived in the anomalous old English capacity measures and weights of the United States. In

Great Britain those units of capacity were swept away and on the recommendation of Dr. Young and his fellow commissioners the single series of imperial capacity measures was introduced in 1826, having a tolerable connection with water; and the weights and measures of the British Pharmacopoeia were correspondingly altered, so that in Great Britain

A fluidounce held an ounce (Av.) of water.
A pint held 1¼ pounds (Av.) of water.
A quart held 2½ pounds (Av.) of water.
A gallon held 10 pounds (Av) of water.
A peck held 20 pounds (Av.) of water.
A bushel held 80 pounds (Av.) of water.
A quarter held 640 pounds (Av.) of water, etc.

The statement of specific gravity is by reference to water, another illustration of the common consent to its use as a standard.

In surveying also there was a relationship in the old measure attributed to the ingenuity of Edmund Gunter; there was a simple relation between length and area. Gunter's chain, which has been to considerable extent superseded by other units, had 100 links, and was 1/10 of the furlong, while the square chain was 1/10 of an acre. The decimal subdivision was an important feature of this land measure.

The measurement of time and of arcs and angles exhibits a survival of a little bit of an ancient comprehensive sexagesimal system of arithmetic. Everybody knows that sixty seconds make a minute, and sixty minutes make a degree or hour. The correspondence between the measurement of arc and the measurement of time is unmistakable, though not very close; since fifteen degrees correspond to an hour and fifteen minutes of arc to a minute of time, fifteen seconds of arc to a second of time. The system from which this originated extended very much further; the second was divided into sixty parts and successive subdivision by 60 was continued; whereas now complication is introduced by dividing seconds decimally. Other multiples of 60 were also used in Asia.

(To be continued.)

Notes.

Teachers are requested to send in for publication items in regard to their work, how they have modified this and how they have found a better way of doing that. Such notes cannot but be of interest and value.

PHYSIOLOGY.

Hygiene as a factor in education is discussed by Mr. Geo. A. Soper, in the November number of the *Educational Review*. Hygiene is not thoroughly taught in many schools, the cause of temperance being confused with that of hygiene. Teachers who are especially prepared receive no suitable recognition for their services. Facilities for higher training in hygiene in the United States are thought to be inadequate. Only in Vermont is provision made for training health officers. Sanitary instruction in medical schools, even, is not accorded a very important place; yet the outlook for better instruction is good and the future looks more hopeful.

Is color-blindness preventable? is discussed by Alida S. Williams in the *Educational Review* for November. After giving the current views, many having reference to imperfections or lesions in the eye or transmitting parts, and percentages—4.5 per cent in men and only 0.4 per cent to 0.6 per cent in women—the writer agrees with a minority of observers that the fault is in interpretation and therefore psychic and curable in future generations. The writer thinks "that disuse is the true explanation and cause of color blindness, which is indicated, if not fully proved, by the fact that little boys show no traces of this weakness when they are taught as their sisters are." This statement is borne out by an examination of 580 children in a primary school who have been well taught in colors and only one was color blind.

L. M.

This fine appeal quoted in *American Medicine* from the headworker of the College Settlement of Philadelphia, is worth quoting again:

"To say 'congested quarters, poor water-supply, surface drainage and privy-wells, the street as playground, the malodorous heat of our nights,' is one thing; to *feel* the murderous quality of these conditions is quite another thing. To aid in changing for the better the condition and the people who suffer and die from them—none the less because they are often ignorant of and indifferent to, or sometimes even the cause of, their own loss and destruction—this is yet a third thing, but the greatest, excelling knowledge and feeling, as charity surpasses faith and hope."

The Dietetic and Hygienic Gazette for November reviews the investigations of Duclaux on the influence of intestinal bacteria on nutrition. Many of the bacteria of the alimentary canal of man seem to be

symbiotic. Duclaux experimented with chicks kept absolutely sterile from the time of hatching. The chicks lost weight steadily, the greatest recorded loss being 32 per cent of the initial weight, and all died within one month. During this time the control chicks gained as much as 117 per cent in weight. The sterile birds were constantly eating while losing flesh and strength, and excreting abundantly. Their condition changed almost immediately, however, to one of natural health and growth as soon as a little of the excrement of the control birds was added to their food, thus supplying them with the normal flora of the alimentary canal.

Cigarette Smoking Among Juveniles.—A number of school boards in England have undertaken a crusade against cigarette smoking among young boys. The Plymouth board has issued circulars to the parents of children under their charge, calling attention to the growth of the habit and its pernicious influences, and at Leeds the board has sought the assistance of eminent medical authorities in an effort to curtail the habit. Other school boards have submitted reports, commenting on the mental, moral and physical deterioration of the cigarette smoker, as observed in the schools under their charge.—*American Medicine.*

The city of Providence sends to the teachers in the public schools a circular on the teaching of cleanliness, of which the following is a portion, as reported by Dr. Charles V. Chapin in *Medical News*:

TEACH THE CHILDREN

Not to spit; it is rarely necessary. To spit on a slate ,floor, or sidewalk, is an abomination.

Not to put the fingers into the mouth.

Not to pick the nose.

Not to wet the finger with saliva in turning the leaves of books.

Not to put pencils into the mouth or moisten them with the lips.

Not to put money into the mouth.

Not to put pins into the mouth.

Not to put anything into the mouth except food and drink.

Not to swap apple cores, candy, chewing gum, half-eaten food, whistles or bean blowers, or anything that is habitually put in the mouth.

Teach the children to wash the hands and face often. See that they keep them clean. If a child is coming down with a communicable disease, it is reasonable to believe that there is less chance of infecting persons and things if the hands and face are washed clean and not daubed with the secretions of the nose and mouth.

Teach the children to turn the face aside when coughing or sneezing if they are facing another person.

Children should be taught that their bodies are their own private possessions, that personal cleanliness is a duty, that the mouth is for eating and speaking, and should not be used as a pocket, and the lips should not take the place of fingers. F. W. R.

Book Reviews.

A Laboratory Outline of General Chemistry. By ALEXANDER SMITH, B. SC., PH. D., Associate Professor of Chemistry in the University of Chicago. Second Edition, revised. 13x19 cm., and ix+107 pages. The University of Chicago Press, 1902. $0.75.

This manual is of particular interest to teachers in secondary schools as showing what the author of "The Teaching of Chemistry" considers the proper course in the laboratory for students in general chemistry. The emphasis laid on quantitative work and the thorough-going use of the ionization theory merit special mention. Teachers of chemistry in secondary schools will find much that is suggestive and helpful in the book.

C. E. I.

Guide to Preparation Work in Inorganic Chemistry for Students of Chemistry and Pharmacy. By DR. REINHART BLOCHMANN. Translated by JAS. LEWIS HOWE. 18x14 cms. 73 pages. Department of Chemistry, Washington and Lee University, Lexington, Va., 1902. 60 cents.

The scope, arrangement, and detailed directions of this book adapt it for effective use in colleges and in high schools. Teachers who cannot use it with classes will profit by personal performance of the experiments. Over half of the preparations could be done with success by a high school class. The illustrations are excellent, and the typography attractive—features not always found in German-American textbooks.

LYMAN C. NEWELL.

Outlines for Field Studies of Some Common Plants. By C. H. ROBISON, A. M., Oak Park (Ill.) High School. 13x20 cm. 39 pages, paper covers.

According to the prefatory note of the author this is a guide by which first year students of the high school can make independent observations on wild plants during the fall months. In connection with this study "Coulter's Plant Relations" is to be used as a reading book; conclusions are to be brought out in recitations.

In the hands of the author himself or any skilled teacher this scheme would be successfully carried out; but directions that could be used by any teacher or with no teacher, would be more valuable. The outlines consisting of twelve main topics which include the leaf, stem, fruit, seed and a general study of trees develop nearly all phases of the life history of a common plant. Some subjects, such as "leaf arrangement" and " light relation," are treated very much in detail,

while other topics, as pollination, are merely mentioned. After the complete study of the leaf arrangement to obtain light, there is no experiment to show what the reason for it all is. The facts are not well connected; there is no definite aim and unity is lacking. As the author states, he has left the conclusions to be developed in class. But would it not be better to have the pupil develop his own conclusions first, and then discuss them in class with the teacher?

Though several plants are mentioned under each head, a beginner would probably be unfamiliar with nearly all of them. There are also terms that would be unfamiliar to the amateur. The study of the flower is placed almost at the close, an unfavorable arrangement if the work is done in autumn.

In the primary essential of science training—to require independent observation and thought—with few exceptions, the outlines are excellent. The questions are clearly and simply framed; the student has no doubt as to what he is to do, and at the same time no clue to the answer desired. In addition to the training the student would gain a considerable knowledge of the plants, their habits, and many interesting facts concerning their structure. Besides this the outlines are stimulating to future work in the same line.

Detroit Central High School. BERNICE L. HAUG.

Animal Activities. By NATHANIEL S. FRENCH, Teacher of Zoölogy in the Roxbury (Mass.) High School. 13×19×2.5 cm., and xxi+262 pages. Longmans, Green & Co., New York, 1902. $1.10.

This "first book in zoölogy" aims "to interest and guide pupils in the study of living animals. It is essentially a "natural history, like the old-time books, placing particular emphasis upon general external structure, life histories, habits, ecological relations and general classification. Some attention is given to internal structures and to the general processes of nutrition in various animals. The order of study begins with insects, and after the arthropods it follows the natural order from Protozoa to mammals.

A serious fault of many parts of the book is that too little stress is placed upon practical work as the only basis for sound zoölogical teaching. This is especially true along morphological and physiological lines, the "natural history" phase being well represented by practical work. There is too much emphasis and dependence placed upon descriptions of structures and processes which are in no way involved in the laboratory study outlined in the book; and, moreover, these descriptions are often inadequate, apparently assuming preliminary knowledge on the part of the pupils. These criticisms apply especially to the descriptions of minute structure, internal organs and physiological processes; for example, the term "cell" is introduced without description,

figures or any suggestions for a laboratory demonstration of cells in typical tissues. An extreme case of this emphasis upon mere descriptions is found in the chapter on protozoa and sponges. In order not "to burden this course with the details of microscopic manipulation we must content ourselves with verbal descriptions," and after studying the activites of amoeba in several pages of words and diagrams, a microscope "may" be used to examine Paramecium! Likewise, sponges "are not recommended for the laboratory," but four pages of descriptions and diagrams of sections from a complex sponge, remove all difficulties which the actual objects will surely bring to young beginners!

It is as a "natural history" that "Animal Activities" is commendable. Along this line the practical work is well outlined and there is a large amount of popular and important information about common animals. It is both a good guide and a reader for the study of the very interesting phases of animal life, which are usually included in "natural history" as it is now presented in many high schools. M. A. Bigelow.

Reports of Meetings.

THE PHYSICS CLUB OF NEW YORK.

The nineteenth meeting of the club, held on Oct. 25, took the form of a visit to the Sawyer-Mann Electric Company's works on 23rd street, New York. The various steps in the manufacture of an electric lamp were shown from the preparation of the flanged tubes which hold the platinum wires to the final wrapping and storing of the lamp preparatory to shipment for use. The processes which interested the members of the Physics Club most were the exhausting and sealing of the lamp, the final preparation of the film by coating it with a hydro-carbon compound, the testing the lamp for its candle power. After two hours had been spent in visiting the factory, the club witnessed a demonstration of the Nernst lamp, given by Mr. H. N. Potter, special engineer in the Westinghouse Laboratory. Mr. Potter also gave the members a demonstration of the Hewitt lamp, which, in some respects, was the most interesting part of the morning program. This meeting is the first of its kind that the club has held and it was considered very instructive. After lunch the meeting adjourned.

Reported by R. H. Cornish.

NEW YORK CHEMISTRY TEACHERS' CLUB.

The third meeting of the club was held at the Hotel Albert, New York, on the evening of October 30, 1902. The topic of the evening was: Are the exercises in the syllabus of the College Entrance Examination Board the best that could be devised to develop the conceptions of combining weights and formulas?.

Papers were read: R. W. Fuller, DeWitt Clinton High School; W. J. Hancock, Erasmus Hall High School; C. M. Allen, Pratt Institute, and a general discussion followed.

M. D. SOHON.

THE COURSES IN CHEMISTRY AND PHYSICS IN THE NEW YORK HIGH SCHOOLS.

During the past school year City Superintendent Maxwell appointed committees of teachers to prepare syllabuses of courses in the various high school studies. The Committee on Physics and Chemistry recommended the adoption of the syllabus of the College Entrance Examination Board.

At the October meeting of the New York High School Teachers' Association, M. D. Sohon, chairman of the Committee on Physics and Chemistry, made the following statement:

The Committee on Physics and Chemistry, recommending to the city superintendent the adoption of the syllabus of the College Entrance Examination Board, has kept in view the fact that, to graduate from the high schools of New York, the pupil must hereafter pass these examinations, and, as so large a proportion of these pupils desire to enter higher institutions, these requirements must represent the minimum, to be considered. Further, as the position of these subjects in the school curriculum has been changed, the committee did not consider it advisable to suggest any modification until it had received a fair trial in its new position in the school.

The course in physics has been developed by the experience of many years in various schools; it is preëminently a laboratory course for individual instruction, and aims to teach the pupil carefulness, accuracy and judgment.

The instruction is: (*a*) Laboratory exercises (35); (*b*) demonstration or lecture, recitation; (*c*) textbook study. The first term (half year) is to be devoted to the study of Mechanics and Sound, the second term (half year) to Heat, Light, Electricity and Magnetism.

The exercises are fairly distributed, no one branch being slighted or unduly emphasized, and in number the exercises are sufficient to permit a large amount of freedom in selection and method of presentation.

Hitherto in Manhattan and Bronx this course has occupied five hours per week in the fourth year; in some schools of the city this

amount of time has been exceeded. The new course of study introduces it into the *third year* (five hours per week, one of these to be unprepared to pupils who have not in the previous year studied science.

This fact places us in a serious position. The course, as outlined, has been subjected to repeated experiences and criticisms, and at present is, I believe, the course most desirable to be pursued in our school, but it must be borne in mind that we are about to attempt to accomplish in practically *four hours per week of the third year* what we have hitherto regarded as demanding *five hours per week of the fourth year.*

How can this be done? The only method that seems practical is to insist on the subdivision of our usual classes into such units as can be successfully handled.

Compared with the syllabus in physics, the chemistry syllabus is for equal grades of pupils somewhat more difficult. This course is also experimental and is based on the same plan as the physics syllabus.

The course, as outlined, is very broad, touches most of the common and important materials, processes, general chemical phenomena, and their application in daily life and commerce.

This syllabus is more recent and has not yet been subjected to such extended criticism as has the physics syllabus, and while an excellent course is outlined, or may be developed from it, in its present form it can scarcely be considered as well developed or as well balanced as is the physics, and much more is left to the discretion of the teacher.

It seems as if the study of the non-metallic elements is unduly emphasized and the metals slighted. The facility with which the non-metals lend themselves to laboratory demonstration accounts for this apparent partiality, and it must be corrected by the teacher. (See examination *questions.*) More recent theory as to the nature of solution is touched upon and formula worship relegated to a subordinate position (expressly stated in syllabus, but apparently overlooked by some of the examiners).

In both the courses the teacher has a very large amount of freedom. The work outlined is of a high grade and is of such character as not only to meet his college requirements, but affords a systematic practical training and furnishes information which will be of future value, and, if a fair standard be maintained by the C. E. E. Board, I believe these courses in physics and chemistry will prove all that is necessary or desirable in our high schools.

NEW YORK ASSOCIATION OF BIOLOGY TEACHERS.

The third meeting of the association for the year 1902 was held at Erasmus Hall High School, Brooklyn, May 16.

Mr. J. E. Peabody of the Peter Cooper High School was the first

speaker, his subject being "Induction in Biological Courses." There are five steps in induction. First, observation of facts; second, comparison of facts; third, induction. We might stop here, but we need to go farther in order to see if more facts conform. Therefore, fourth, deductive reasoning and consequently, fifth, modification. As an illustration, suppose we have studied endogenous and exogenous stems and have noted the veinage of their leaves. We might conclude that all stems having parallel veined leaves would be endogenous, which is not the case. Hence the need of further observation of facts, deduction and modification.

Mr. M. A. Bigelow of the Teachers' College gave an outline of Mr. T. E. Lloyd's paper on "The Framing in Method of Thought Received in the Study of Biology", Mr. Lloyd not being able to be present. An abstract of the paper is as follows:

Educators generally accept the doctrine that work in science must be so presented as to give training in the inductive method of thought (the scientific method in the broad sense, as used by Karl Pearson) with due regard to the importance of the doctrine of probabilities. To use the more common expressions, students must "observe facts" and "draw correct inferences."

As a matter of fact this method as applied to biological teaching is not generally used. In common practice we ILLUSTRATE an important principle or law; we usually do not generalize from a sufficient number of carefully ascertained facts.

This is not in itself a fault. It is merely a practical necessity. Time and other limitations forbid even an approach to the strictly inductive method.

The teacher must be careful to distinguish between the actual result of an experiment or observation and the general law of which such is an illustration. It is only in this way that proper appreciation of the value of evidence and of degree of probability will characterize the results of science teaching.

Mr. Bigelow then spoke on the subject of "Developing Intellectual Power." The paper discussed the value of biology in the intellectual life of a liberally educated man whose interests touch upon the fields of cosmic philosophy, sociology, psychology, ethics, and religion. The relation between biological facts and generalizations and these phases of human knowledge was reviewed in outline. Finally the suggestion was made that even an elementary course of biology may give the student at least a viewpoint which in later year may be important in giving the proper perspective to philosophic studies. Such a result does not necessitate that the biological work should digress in order to point out its bearing upon other fields of knowledge.

The next speaker, Mr. A. J. Grout of the Boys' High School, Brook-

lyn, gave an interesting talk on the "Value of Biology as an Additional Interest in Life." Very few boys make use of their physics or chemistry in after life. Few subjects are able to be used. But knowledge of and an interest in living things should afford a source of inexhaustible pleasure and satisfaction. Few people can take an intelligent interest in nature. People in the city waste their time on things unworthy of them and people in the country are unable to get any pleasure from the multitudinous phases of nature with which they are surrounded.

We should so teach biology that it will afford a never-ending interest in life.

Mr. H. A. Kelley of the Ethical School of Culture, Manhattan, spoke on the subject: "In How Far are the Present Courses in Biology Adapted to the Need of the Adolescent?"

We should not attempt to do college work in the high school. The instructor may be an excellent investigator, but a poor teacher. Three things are to be considered in the preparation of a teacher. First, appreciation of the subject matter. Second, knowledge of the child's state of development. Third, the power to transmit. We must recognize the various periods in a child's life and present the subject in accordance with the child's needs and his state of development.

The reading of these papers was followed by a general discussion of all of them.

Reported by ARTHUR E. HUNT, Temporary Secretary.

The fourth meeting of the current year was held in the Board Rooms, Board of Education Building, 59th street and Park avenue, at 8:15 p. m., November 7th, with President H. R. Linville in the chair.

An unusually large number of members and friends, including several principals and superintendents, had gathered to hear what was a most interesting and instructive evenings' discussion on the following topic: "What Understanding is Possible Between High Schools and Colleges with Regard to College Entrance Work in Biology?"

It was expected that Dr. E. B. Wilson, of Columbia University, would be present to give his views on the zoölogical aspect, but owing to his illness and enforced absence, Dr. Linville opened the discussion with an account of the general work attempted by the course in biology as now given in the high schools of Greater New York. Half of each year being devoted to botany and zoölogy, with a treatment of the subject from the physiological aspect. The immaturity of the student makes necessary a course of external morphology with reference to the internal morphology only through dissection made by the teacher and given with the view of explaining the physiological processes that take place. Stimulation of the student by natural history and drill then

give the main educational values to the course. The future student in chemistry or physics is thus started with the laboratory idea. The addition of the fourth year elective in biology will, it is believed, do much toward giving the desired college entrance course.

Dr. Linville then introduced the speaker of the evening, Prof. Wm. F. Ganong of Smith College. He spoke in part as follows: "An understanding is possible between high schools and colleges with reference to a college entrance option, for it already exists and several students have taken advantage of it at Smith. The course must be a full year in either zoölogy or botany. Out of 13 points of the Smith entrance examinations, biology counts as 4 points.

"The college must accept a good educational course in the high school. It must be in a general way as equivalent to their introductory course and for this reason should be a full year of either zoölogy or botany. A half-year course cannot well be utilized by the college. Biology must be made of as much value as the other sciences. Botany and zoölogy are not isolated subjects, but part of a general educational plan from the lowest to the highest grades. An actual distaste to this kind of work among students is often due to the discontinuity of their science work.

The characteristic of a good course in botany should be one which will give the student a good idea of the science as it stands at present Anatomy, physiology, ecology and taxonomy should all have their place in the course. In a general way one-third of the year might be given respectively to anatomy, physiology and form-relationships."

The teacher was referred to the third report of the committee appointed by the society for plant morphology and physiology printed in the May issue of this journal, and copies were distributed to all present.

An interesting discussion followed Dr. Ganong's address, participated in by Prof. Lloyd of the Teachers' College, Dr. McDougal of the New York Botanical Gardens and Messrs. Peabody, Kelley, Goodwin and others of the city schools. The question was raised by Drs. Lloyd and Kelley as to the interest of the child in biological science in the fourth year of the high school. Some doubt was expressed as to the child's attitude toward the subject after the interest of the first year had worn off. After a general discussion the meeting adjourned until December 5th.

A day or two after the meeting Dr. E. B. Wilson kindly offered to send the writer his views on the subject discussed at the meeting. The following letter expresses briefly the points under discussion.

My Dear Mr. Hunter:

My views regarding biology in high schools and its relation to biology in college are somewhat as follows.

I think we should distinguish very clearly between biology as a

subject for college entrance and biology as a study pursued for its own sake in the high school.

As regards biology as a subject for entrance, I have always been of the opinion that elementary chemistry and physics form a better preparation for such courses in biology as we try to give than zoölogy, botany, or combination courses in biology in the schools; and I would much prefer to teach students well prepared in chemistry and physics, and with no knowledge of biology, than those who have had a year of biology without adequate elementary training in the other sciences. For these reasons, while I am most heartily in favor of biological instruction in the schools, as complete and extended as time will allow, I am not very favorable toward their recognition as entrance subjects. If, however, they are offered as entrance subjects, I am decidedly of the opinion that for this purpose a whole year's course in botany or in zoölogy is preferable to a mixed year of general biology. My own experience has demonstrated to me the fact that general biology in the form in which I try to teach it can only be properly appreciated by students of rather mature minds, and for this reason I have always taken the position that the course in general biology should not be taken before the junior year, as is our practice at Columbia. To teach general biology of this kind to high school students is of doubtful utility and obviously quite out of the question in the earlier years of the school course. I therefore think than an entrance requirement in zoölogy should include (1) an acquaintance with the essential facts of physiology in the higher animals, with especial reference to human physiology, and (2) a course in zoölogy proper, with especial reference to comparative anatomy and to ecology. It appears to me that the more children can be taught of general natural history of the old fashioned kind the better, including such things as the habits and distribution of animals, the external features of their development and metamorphoses (tadpoles, insect larvæ, and the like) and something too of elementary systematic zoölogy, so that they may recognize our commonest animals, though I appreciate the difficulties of doing this in a city school. These things may well come in the earlier years of school life. The study of elementary comparative anatomy should be deferred until the later years.

In the case of students who are taking only a high school course, I think it might be practicable to give an effective course in general biology of a simple kind, including in this the general principles of comparative physiology, the relations of plants and animals, the work of bacteria, and even some of the problems of evolution; were I giving such courses I should treat them very differently from those that I give to college juniors.

Very truly,

EDMUND. B. WILSON.

Reported by G. W. HUNTER, JR., Secretary.

EASTERN ASSOCIATION OF PHYSICS TEACHERS.

The thirty-fourth meeting was held at the East Boston (Mass.) High School on Saturday, November 8, 1902. The members were the guests of Mr. W. H. Godfrey, teacher of physics and chemistry in this school. A portion of the morning was devoted to an inspection of the laboratories. The building is new and the equipment thoroughly modern and servicable. At the business meeting it was voted to extend the limit of active members to 75, and to provide for unlimited associate membership.

The committee on apparatus, through its chairman, Mr. C. H. Andrews, reported on the Nernst lamp. The following is a brief abstract:

"The lamp is an invention of Professor Nernst, and although it has only quite recently been perfected so as to be placed on the market, its essential principles were made public some years ago. The patent rights for the United States have been purchased by George Westinghouse and large sums of money have been expended by him in bringing the lamp to its present state of perfection.

"The light emanates from a filament or glower about three-fourths of an inch in length, of a composition of a rare earth which, at the ordinary temperature, is of such high resistance as to be practically a non-conductor of the electric current, but which when sufficiently heated becomes a conductor and becomes very highly incandescent, glowing with an intense white light.

"It is necessary, to light the lamp, to first heat the glower. This Professor Nernst accomplished by a match or a small alcohol lamp; but Mr. Westinghouse has perfected an arrangement by which the heating is brought about by two small heaters, so called, which consist of coils of platinum wire imbedded in clay and placed on either side of the glower. When the electric current is turned on, it first flows through the heaters, which raise the temperature of the glower until it becomes a conductor, when it suddenly becomes incandescent; while an automatic cut-off throws the heaters out of the circuit.

"The chief advantage of the lamp lies in its great economy. A single glower will give 50 C. P. with a ground glass globe and 75 C. P. without a globe, with an expenditure of only 83 watts, or about one watt per C. P., whereas an ordinary lamp requires from 3 to 4 watts per C. P., according to its age. The light is also very white and if properly shaded, very agreeable to the eye. The life of the glower is about 800 hours, and it may be easily replaced at a cost of twenty-five cents. At present, owing to some electrolytic action, the lamp can be used only on alternating currents, but it is hoped that this difficulty may be soon overcome. The light, coming as it does, from a very small area, casts a sharp shadow, and it would seem that those users of a stereopticon, who are looking for a substitute for the arc lamp, which is more or less troublesome to

keep in adjustment, will find the Nernst lamp a welcome addition to their projection outfit. On 220 volt circuits three glowers may be used in a single lamp, giving a light of about 200 C. P."

The committee on magazine literature, Mr. W. F. Rice, chairman, presented the following list of articles on physics, which appeared from June to October, 1902.

MECHANICS.

Mechanical Engineering of an Electric Railway. Howard P. Quick. *Engineering Magazine,* July.

Measurement and Calculation. R. S. Woodward. *Science,* June 20.

Recent Progress in American Bridge Construction. Henry S. Jacoby. *Science,* July 4.

LIGHT.

Lighting of Railway Trains in Europe. H. Guerin. *Engineering Magazine,* October.

Photographing Sound Waves. *Scientific American,* Vol. LXXVII, 34.

New Theory of Light and Colors. Sir Isaac Newton. *Popular Science Monthly,* September. Reprint of letter to Royal Society, February 6, 1672.

ELECTRICITY.

Elementary Principles of the Electro-Magnet. *Science and Industry,* Vol. VII, 317, 346, 421 and 482.

Enclosed Arc Light. *Science and Industry,* Vol. VII, 404 and 457.

Roentgen Ray Burns. *Scientific American,* Vol. LXXVI, 342.

Transformers. R. B. Williamson. *Science and Industry,* Vol. VII, 359.

The Ions of Electrolysis. A. Crum Brown. *Science,* June 6.

Curious Electrical Forms. Anabel Parker. *Century,* July.

Radio-Activity. A New Property of Matter. R. K. Duncan. *Harper's Monthly,* August.

Newest Definitions of Electricity. Carl Snyder. *Harper's Monthly,* October.

High Speed Electric Interurban Railways. Geo. H. Gibson. *Engineering Magazine,* September.

Physical Limits of Electric Power Transmission. Alton D. Adams. *Engineering Magazine,* October.

HEAT.

Science of Steam Making. J. C. Parker. *Science and Industry,* Vol. VII, 240.

Steam Turbines. William Brulingham. *Science and Industry,* Vol. VII, 351.

The Heat Balance. R. T. Strohm. *Science and Industry,* Vol. VII, 311.

The Modern Engine. *Science and Industry,* Vol. VII, 315.

MISCELLANEOUS.

Diamonds by Electric Furnace. *Scientific American*, Vol. LXXVII, 141.

Further Development of Niagara's Power. *Scientific American*, Vol. LXXVII, 234.

United States and Metric Systems. *Scientific American*, Vol. LXXVI, 343.

The Laws of Nature. S. P. Langley. *Science*, June 13.

Peter Guthrie Tait. C. K. Edmunds. *Popular Science Monthly*, June.

Mr. George W. Earle, vice president of the association, delivered the annual address of that officer. The following is a summary:

"The State Teachers' Association of New York, in answer to a circular letter sent to the leading business and professional men of New York city received over four hundred replies. These men were unanimous in stating that the schools in fitting boys for useful employment, 'ought to lay great stress upon character building, upon the training of the morals and manners, and inculcate an ability to *follow instructions*.

"In helping to train and develop pupils along these lines, would not the science teacher be a most powerful help? What could assist in 'character building' more than hard and honest work in the laboratory at some difficult quantitative experiment, where the pupil must rely upon his own efforts and depend for success upon truthful observation, accurate readings, and a *strict following out of directions?* Does not every laboratory teacher feel, from his own experience, that no subject taught in the public schools has greater influence in training pupils to thoughtfulness, observation, reliability and to the importance of *obeying orders*, than the study of the sciences?

"Are the teachers of science doing all the good in this direction to the pupils in the high schools that it is possible for them to do? They are not. They do not come into contact with as many pupils as they ought.

"In general, the number taking science in the high schools is very small. There are usually only two science teachers in a school. These two seem satisfied with small divisions. The number of pupils taking physics has a tendency to become less and less each year.

"If the sciences are as important as science teachers claim, and as leading educators claim, this is to be regretted. The laboratory teacher is not that strong factor in helping train boys and giris for a useful life that he ought to be.

"In every large school there are many teachers of mathematics, of history. Why not also many teachers of physics, chemistry and biology; and all pupils be required to take a certain amount of these sciences?

"Boys and girls would not only be benefited by the discipline resulting from such studies, but their lives would be made happier and capable of greater usefulness."

Mr. J. W. Hutchins reviewed Smith and Hall's "The Teaching of Chemistry and Physics" favorably.

After lunch, the members listened to an address by Professor H. W. Morse of Harvard University on "Electricity Direct from Coal." The address was largely historical and speculative. He said the main problem was to get carbon and oxygen to unite so that their union would give a current of electricity. After discussing several attempts to construct such a cell, he said, in conclusion: "No such cell has been successful up to the present. We have brought the dynamo and the storage battery to perfection. No one can say what the next ten or fifteen years may bring out of the investigation concerning these cells."

Reported by LYMAN C. NEWELL.

Correspondence.

EDITOR SCHOOL SCIENCE:

The article in the December number on the "Examination of Baking Powders" suggests "to other teachers the possibility of similar experiments." Perhaps some work done along this line by advanced students at the Phillips Exeter Academy may be of interest.

Three brands of so-called cleansing "potashes" on the market were analyzed qualitatively and were found to be mixtures of from two to four compounds each. The interesting fact was brought out that the trade names were not always safe indicators of the compounds actually present. Quantitative experiments, devised partly by the students themselves, showed that the ingredients were present in proportions varying from 2 to 90 per cent for those ingredients present in smallest and largest proportions, respectively.

To get percentages for comparison it is necessary to use the same can for all determinations, for it was found that different cans of the same brand varied from 5 to 10 per cent on some ingredients where the experimental error was probably within one per cent. These mixtures were very satisfactory to work with on account of the absence of acid radicals that cause considerable trouble in quantitative methods.

WILHELM SEGERBLOM.

Mathematical Supplement of School Science

Beginning with its third year in March, 1903, SCHOOL SCIENCE will extend the scope of its work by the inclusion of a supplement devoted to problems of secondary mathematical teaching. The supplement will contain from 24 to 32 pages and will be issued four times a year. Its editorial management will be in the hands of Mr. G. W. Myers, Professor of the Teaching of Mathematics and Astronomy, University of Chicago. Mr. Myers also retains his associate editorship of Astronomy on SCHOOL SCIENCE.

The idea of incorporating a mathematical supplement has been in mind from the beginning; but the fullness of time is now believed to have arrived for it. The issuance of the supplement has its conception in these propositions, which are quite generally held by those familiar with the mathematical situation.

1. Science teachers feel that students prepared under current methods of mathematical teaching fail to acquire the kind and quantity of power to use their attainment which is called for in science work.

2. There is wide and well-founded dissatisfaction among those mathematical teachers who have to build on high school preparation, with the feeble grasp of abstract mathematical truth which high school graduates exhibit and with the lack of power in these pupils to appreciate the bearing and import of this truth in dealing with the everyday problems of life.

3. The teaching of secondary mathematics largely through its legitimate uses in science and elsewhere, is a method of demonstrated promise and feasibility of removing, to a large degree, both of these sources of dissatisfaction.

4. The sciences are all becoming more mathematical in character every day, so that mathematical incompetency is becoming rapidly more telling against general educational efficiency and progress.

5. The method of teaching algebra, geometry and a mathematical science abreast and in organic relations to each other as opposed to the tandem method has already borne fruits, entitling it to more general use in the class room than it has hitherto found.

All teachers in any field of mathematics or science who are in general accord with these propositions are invited to coöperate with the editor of the mathematical supplement in a constructive and concerted effort to bring all secondary mathematical teaching up to a level with the best and to elevate the best. Well established criticism, with a distinct constructive purpose, will be cordially welcomed.

Let this coöperation take the direction of contributions from actual class work, where the methods suggested above have been or are being tried; articles embodying in model lessons, or series of lessons, the practical outcome of attempts at the laboratory method of mathematical teaching, at correlated mathematical teaching; and articles, both general and specific, containing the experiences of persons who feel they have something worth while to say to the profession. It is desired, however, that all articles should be sufficiently explicit to render them easily reducible to practice by teachers who are disposed to test their value by class use.

Direct all mathematical correspondence to

G. W. MYERS,
Mathematical Editor School Science
6119 Monroe Avenue, Chicago

The supplements will also be issued separately at 15 cents each or 50 cents a year. Remittances should be sent to

The School Science Press
Ravenswood, Chicago, Ill.